The Content-Driven Integration Model in the Mathematics Classroom

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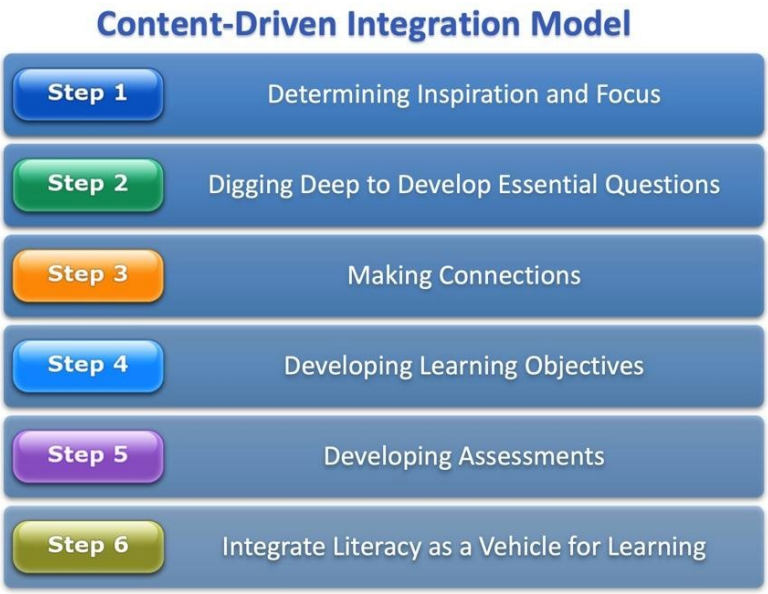
Integrating mathematics with other content areas has many benefits for student learning. For example, students can understand how mathematics topics are used in the real-world. This allows for conceptual mathematical meaning and links to be fostered through genuine discussions (e.g., Czerniak et al., 1999). However, despite the benefits, integration of mathematics with other subjects can be a complicated endeavor, particularly for preservice and novice teachers. How can we help both current and future teachers from elementary through high-school to meaningfully integrate mathematics with science, social studies, and literacy instruction without overwhelming them?

In our roles as a mathematics educator (Amanda) and literacy researcher (Sarah), we spent extensive time working alongside our preservice as well as inservice teachers to create and implement integrated units in collaboration with our science and social studies colleagues. In this work we developed a model, called the Content-Driven Integration model (CDI, Lupo et al., 2021), to support teachers in integrating multiple content areas during instruction using real-world scenarios as a motivator for learning. By providing teachers a model to guide them through integration, mathematics teachers can use their time wisely to bring in meaningful connections with science and social studies and use literacy instruction as a tool in their lessons to emphasize content connections. In this article we describe the model, how it can be applied in the mathematics classroom, provide examples of subject integration for the mathematics classroom, and share how to support preservice teachers in learning how to integrate mathematics with other subjects.

What is the Content-Driven Integration (CDI) Model?

The CDI model was constructed using inspiration from the Backward Design model (Wiggins & McTighe, 2005), while addressing *how* to incorporate multiple subjects into a single unit through a six-step process. As seen in Figure 1, for the first step, teachers determine the driving inspiration for the unit considering the classroom context and the mathematics' content goals. In step two, teachers create a concept map focusing on the main content area to determine the big ideas and essential question(s). Next, teachers use the concept map to find connections to other content areas (step three), and create the content area learning objectives (step four). Then in step five, teachers create the summative and formative assessments for the full unit, including content areas. From this process, teachers will be ready to plan lessons incorporating literacy standards (step six) that will set students up to successfully complete their assessments and meet their objectives.

Figure 1
Content-Driven Integration Model



This step-by-step process was created to make content integration feasible for teachers. By beginning with topic selection, developing motivators to inspire learners, and then looking for other content-connectors, teachers can effectively develop integrated units. The latter steps (developing learning objectives and assessments) are not new to our teachers who are already familiar with Backwards Design. By integrating literacy *last,* literacy serves as a vehicle for learning the content by teaching the subject matter (see Lupo et al., 2021 for more information on how and why to do this).

See it in Action: The CDI Model in Mathematics

The CDI model is an effective tool for supporting teachers in integrating across disciplines, so what does it look like for a mathematics teacher?

Step 1: Use Real-World Scenarios to Contextualize Mathematics

In the first step, teachers *select mathematical content and the connected real-world context*. When instructing preservice teachers, establish that they can begin this integration process either by exploring the mathematics state standards first or starting with a problem students face in their community (*context*). In either case, this provides teachers the opportunity to incorporate social justice issues into their mathematics classroom.

For example, we began our integrated unit by finding an issue from our local community that could motivate students' learning. Our students became aware of areas that lack clean drinking water in their community. Therefore, in our planning, we began exploring topics related to water insecurity and water cleanliness. We identified a book (*You*

Wouldn't Want to Live Without Clean Water by Canavan et al., 2016) that could engage students' interest and provide them background information on how unclean water can cause illness.

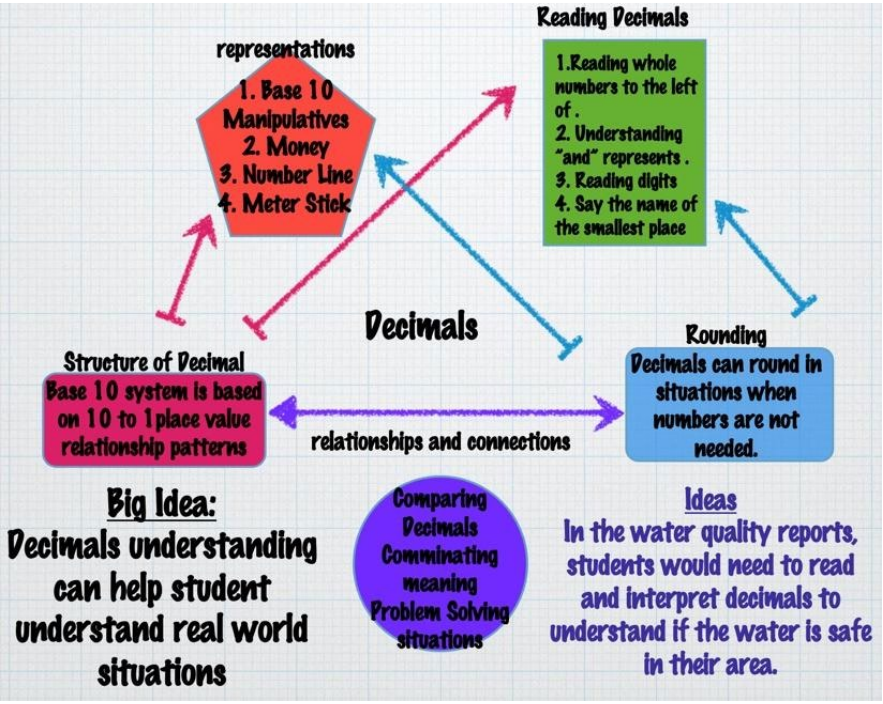
Since our integration process began through the selection of the context, we needed to find a mathematical content connection with the real-world context. To understand if a community has clean water, citizens must be able to read and compare decimal values on their area's water quality report published by their state government. We noticed that the fifth-grade mathematics standards require students compare decimals to the thousandth place which provides the mathematic content connection to the issue of water cleanliness. Thus, we explored the topic of water insecurity around the concept of reading decimals. We planned to have students compare water quality reports, in particular, levels of lead and copper in the water, and determine which localities had safer drinking water. Given that lead or copper is dangerous for health, the significance of this issue would serve to motivate the mathematical concept of comparing decimals. In traditional mathematics classrooms, comparing decimals can be taught through worksheets that compare just numerical values. However, understanding that comparing decimals will help them determine if a population of individuals are able to drink their water, motivates our students to *want* to compare decimals.

Step 2: Digging Deep to Understand the Mathematics Concept

After identifying the motivating context and mathematics content, teachers develop the unit's essential question(s*)*, which should embody the main concept of the integrated unit and does not have an obvious answer. We suggest beginning this process by having teachers examine their state's standards and/or the state's conceptual framework to create a concept map to "go deep" to truly understand the mathematics content. This is particularly important for preservice teachers because their understanding of content is often less developed and they have less experience writing essential questions.

Below we depict an example of a concept map for our unit on water quality (see Figure 2). Our concept map shows key aspects of decimal comparison, such as understanding the place value in the base 10 system, that are necessary to compare values and connections to the motivating context (water insecurity) to display a central focus of the unit. From the decimal concept map, we created our essential question: *How do I know what affects the water I drink?*

Figure 2
Decimal Concept Map



Step 3: Connecting Mathematics to Other Subjects

In step three, teachers *use the essential question(s) to find connections with other subjects*. Starting with the essential question created from the decimal concept map, we explore meaningful connections to science and social studies by looking at the state standards for each subject (see Table 1) then connect those topics in a second concept map that show the connections across all of the content areas in an interdisciplinary unit (see Figure 3). Through our exploration of the fifth-grade standards, we found clear connections to understanding what affects the water that students drink. In fifth grade science students learn about the properties of matter, so in our unit they can explore different properties of matter while connecting back to water quality. In social studies students learn about the importance of being an active citizen in society, which includes solving community issues (such as water quality). We then expanded our concept map to model how all three subjects can be integrated to provide a deeper context for exploring our main mathematics concept, decimal comparisons.

Although creating two maps may appear complicated, we found that preservice teachers benefited from a second concept map depicting the essential questions with the subject specific goals to cipher the connections between topics. For example, in our second concept map, preservice teachers can now connect ideas like comparing decimal values in mathematics with measuring of materials in science and how those ideas converge around what affect the water they drink, the essential question.

Table 1
State Standards Addressed in the Integrated Unit

Science Standards	Social Studies Standards	Mathematics Standards
VA5.7 The student will investigate and understand that matter has properties and interactions. Key ideas include a) matter is composed of atoms;	VA.1 b) Analyzing the impact of geographic features on people, places, and events to support an understanding of events in Virginia history	VA 5.2b) Students will compare and order decimals through thousandths in a given set, from least to greatest and greatest to least.
VA5.7 The student will investigate and understand that matter has properties and interactions b) substances can be mixed together without changes in their physical properties;		
VA5.7 The student will investigate and understand that matter has properties and interactions. Key ideas include and c) energy has an effect on the phases of matter.		

Figure 3
Connecting Subject in Concept Map

Step 4: Developing Learning Objectives

Next, we must *determine the unit learning objectives developed from our content learning goals and standards*. During this step, we think about key information or skills students need to learn to answer the essential question(s). With our preservice teachers, we identify what students need to understand, know, and do for each content area in the unit.

The *understand* learning objective focuses on the big ideas connecting all of the concepts in an interdisciplinary unit. The essential question is a key starting place to identify the *understand* objective. The understand objectives should help learners answer the essential question (with the caveat that students can answer the essential question in many different ways)! For example, as shown in Table 2, the understand objective for mathematics (understand decimals are used to describe various quantities) must occur to figure out how to read a water quality report to know what is affecting water in a particular area.

Table 2
Learning Objectives for Integrated Unit

Content Subject	Understand Objective	Know Objective	Do Objective
Science	I will understand that the properties of matter help distinguish between different substances.	I will know a mixture is when two substances mix together and keep their identifying properties.	I will be able to identify a mixture.
		I will know a solution is a mixture in which one	I will be able to compare and contrast mixtures and solutions.
		I will know a substance is uniformly dissolved in a liquid.	I will be able to explain what happens when two or more substances are mixed together.
		I will know the different states of matter have different properties.	I will be able to compare the properties of the different states of matter
Social Studies	I will understand that people interact with the environment in ways that affect the way they live and the environment they live in.	I will know that many indigenous people try to protect the Earth through activism and action.	I will be able to explain how humans interact with one another and the environment in ways that can protect and/or harm the earth's natural resources.
		I will know that my own actions can protect and/or harm the environment.	
Math	I will understand that decimals are used to describe various quantities.	I will know the decimals' place value and what it means compared to a whole.	I will be able to compare multiple decimals to determine which value is greater in the quantity.

To identify the learning objectives focusing on what the students should *know* and what the students should be able to *do*, we can start by examining the language in the standards. The nouns provided in the standards can inform the *know* learning objectives. For example, students must "know" a decimals' place value to understand decimal comparisons. The *do* objective focuses on the verbs, which imply disciplinary skills and/or practices students will use to demonstrate their knowledge of the content. For example, this is where the students demonstrate their knowledge of specific mathematics strategies like comparing decimals by placing values on a number line.

Step 5: Developing Assessments to Evaluate Mathematics Learning

Honoring Backwards Design (Wiggins & McTighe, 2005), we *create assessments to determine if students meet the learning objectives.* In order to assess multiple subjects in one assignment, we rely on more open-ended projects rather than multiple choice tests to support a meaningful demonstration of knowledge. We found that we need to provide instruction around these different choices (brochures, skits, posters, research paper) to broaden our preservice teachers concept of assessment beyond tests.

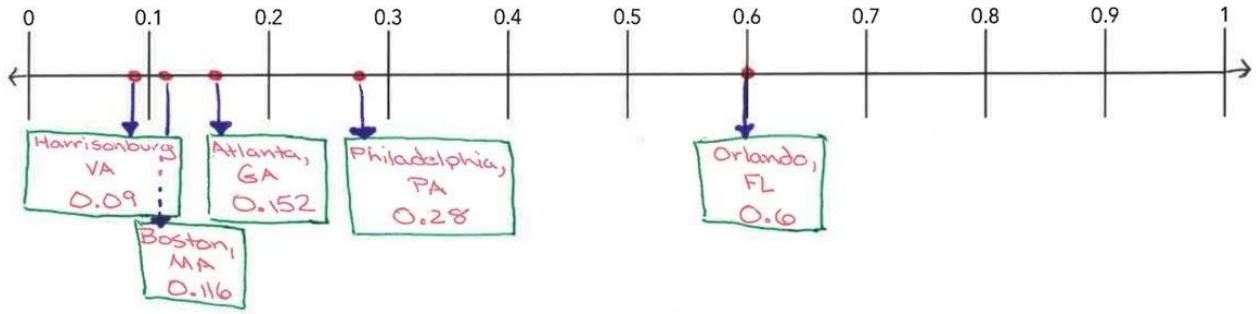
For example, in our water quality unit, the students had a three-part project. First, students selected five different cities and compared the level of copper in each city's water, using government reports of water quality as a source, thus solidifying their understanding of how to read decimals. In part two, the students demonstrated their knowledge of comparing decimals by placing those found values on a number line (Figure 4). Finally, they analyzed their findings in a paper explaining the results of their analysis using the following questions as a guide:

1. What does the decimal values on the number line tell us about the drinking water in each area and why? (Mathematics assessment)
2. How is the drinking water affected by matter and why? (Science assessment)
3. What can humans do to protect earth's natural resources? (Social Studies assessment)

Collectively this assessment allowed us to determine if they could accurately compare the decimals and apply their knowledge to social studies and science concepts. Further, we can use the assessment to gauge their writing ability as well.

Figure 4

Copper Concentration in Drinking Water in Parts Per Million (PPM)



Step 6: Integrate Literacy as a Vehicle for Learning Mathematical Concepts

Finally, we *integrate literacy as a vehicle for learning*. This includes finding relevant texts and including writing opportunities to maximize learning of science, social studies, and mathematics concepts. In this unit, students watched a video about the Flint Michigan water crisis (MLive, 2016) and, as mentioned earlier, a book about the importance of clean water. As you can see, we broadened our definition of texts to include visual texts that support content learning and offered writing opportunities to support both literacy and content. For example, students watched a video by Bill Nye

the Science Guy (Nye, 2015) on atoms to help understand how matter changes phases at the particle level to deepen their understanding of how water can become contaminated. After watching, students wrote an explanation of how the particles moved to change phases. In this way, literacy was used to support learning of the other subjects and the other subjects provided a meaningful context for literacy learning. By selecting texts *after* doing the deep-thinking work of the unit, our preservice teachers chose better quality texts that truly taught the content and engaged their students with the mathematics, science, and social studies concepts they were teaching.

Conclusions

Integration is a powerful tool, but it requires thoughtful planning to be done effectively. To scaffold this integration process, we created a CDI Unit Organizer for Mathematics (Figure 5) to support teachers thinking through integration. This organizer which we implement in our methods courses helps guide preservice teachers through the CDI model. In our experiences working with teachers, this template has helped teachers work smarter rather than harder so mathematics integration is done appropriately as well as effectively using relevant content and motivating contexts. As one fifth grade teacher, explained,

> *One thing that continues to surprise me is how it all comes together in the end. Planning this type of project, especially the first few times, can feel very daunting. However, it's kind of like putting together a puzzle. Once you've organized your pieces [using the CDI method]… the rest seems to naturally take shape and become more clear. (Lupo et al., 2021, p.249)*

Figure 5
CDI Unit Organizer for Mathematics

Step 1: Determining Driving Inspiration and Focus Mathematics Content

Main Focus Mathematics Goal:
Context:

Step 2: Digging Deep to Develop Essential Questions

Concept Map:
Essential Questions:

Step 3: Making Connections

Science:
Social Studies:

Step 4: Developing Content Learning Objectives

Content	**Understand:** *What are the broad generalizations the students should gain?*	**Know:** *What are the tools, vocabulary, symbols, etc. the students will gain through this lesson?*	**Do:** *What are the specific thinking behaviors/procedures students will be able to do through this lesson?*
Science			
Social Studies			
Mathematics			

Step 5: Develop Assessments

Ideas for Summative Assessment:
Ideas for Formative Assessment:

Step 6: Integrate Literacy as a Vehicle for Learning

What texts can support this learning:

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