Indiana Mathematics Teacher

Official Journal of the Indiana Council of Teachers of Mathematics

Fall 2012

Welcome to the revival of the Indiana Mathematics Teacher Journal!

Thanks to Dr. Doris Mohr and Dr. Rick Hudson, we have returned to a traditional print journal containing contributions from several mathematics educators across the state of Indiana.

With new state teacher evaluation guidelines, the adoption of the Common Core State Standards, and budget cuts, most of us are facing additional decisions about what and how we teach. In the midst of the busy days it can become difficult to find ways to keep our focus on improved student learning. The ICTM Board members want to provide support for you and are always searching for new opportunities. Please let us know if you have a need or idea. We hope you are able to take advantage of our organized events such as the annual Fall Conference, Indiana Math Contest, and summer workshops.

Take a few minutes to relax and read the journal. It is my desire that an article will trigger an idea for you to implement in your classroom and that you will find a group of teachers who will join you on the journey. Below are three quotes that help me personally keep a positive attitude, stay focused and move from ideas to actions. I hope they do the same for you as you focus on what you control each day!

"Challenges are what make life interesting; overcoming them is what makes life meaningful."
—Joshua J. Marine

"Patience and perseverance have a magical effect before which difficulties disappear and obstacles vanish."
—John Quincy Adams

"Every accomplishment starts with the decision to try."
—Unknown

Before I close, I'd like to thank you for your commitment to educating students. With dedicated professionals like you joining together with a common vision, we can help shape the future of mathematics education in Indiana. My personal respect and thanks go out to you. The ICTM Board of Directors is committed to improving the support we offer you and is always looking for volunteers. Please communicate your needs and consider volunteering today!

Angela S. Moreman

Angela Moreman, President
ICTM Board of Directors

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About the Journal

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The *Indiana Mathematics Teacher* is a peer-reviewed publication of the Indiana Council of Teachers of Mathematics. The *Indiana Mathematics Teacher* provides a forum for mathematics teachers from pre-kindergarten through college to present their ideas, beliefs, and research about mathematics teaching and learning. We are currently seeking manuscript submissions, and welcome them from preK–12 teachers, university mathematics educators, professional development providers, graduate students, and others with a vested interest in mathematics education. Manuscripts should be written for an audience of K–16 mathematics teachers and should be limited to approximately 1500–2000 words. For more information and full submission guidelines see *http://ictm.onefireplace.org/* or contact the editors at *djmohr@usi.edu* and *rhudson@usi.edu*. If you are willing to serve as a peer reviewer to provide feedback on potential articles, contact one of the editors.

Don't Move on Just Yet! Following up on students' successful solution strategies using "Next step, but deeper" tasks

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Introduction

In this article, we follow others (e.g., National Research Council, 2001) who have compellingly argued that mathematical investigations surrounding a concept are too often "procedural;" that is, they are hyper-focused on teaching and learning procedures that produce the correct answer but are disconnected to deep mathematical meaning. To address this tendency, we offer guidelines for designing *next step, but deeper* lessons based on the notion of engaging and re-engaging students in a series of connected tasks. The subsequent tasks in such series contain different and well-chosen constraints that prohibit or discourage the use of previously-constructed, less sophisticated strategies or representations; instead, they encourage the construction of more sophisticated strategies or representations. We begin our discussion with a scenario that took place in one of the author's mathematics content courses for elementary teachers. We then apply and build upon the existing framework of Stein, Smith, Henningsen, and Silver (2009) to classify the cognitive demands of mathematics tasks and further establish guidelines for developing *next step, but deeper* tasks. Finally, we discuss the implications of such guidelines for mathematics teachers in K–12 or university classrooms.

Task #1 with Pre-Service Teachers

Students often come into our classroom with mathematical understandings that are limited to following procedures that make little sense to them. Oftentimes, familiar algorithms are the only approaches they think about or turn to in order to solve computation problems. We claim that the guidelines for *next step, but deeper* tasks can be helpful for teachers who are interested in helping their students move beyond these initial approaches.

Anna and Janice (pseudonyms), two pre-service teachers enrolled in a university mathematics course for elementary teachers, were presented with the following division problem called the "Sixths Task:" What is *2/6 divided by 10/6*? We felt this task had the potential to engage students in constructing some of the "big ideas" surrounding division with fractions, such as understanding how to determine the whole and use fractions as operators (see Fosnot & Dolk, 2002, and the "implications" section of this article for more discussion of these "big ideas" of fraction learning). The pre-service teachers first used the traditional algorithm that involves inverting the second fraction and multiplying the resulting numerators and denominators. When asked why they inverted and multiplied, they explained that multiplication was the inverse of division; so, with this reasoning, they knew they could use the familiar multiplication algorithm to solve the problem. They were stumped, however, when asked why they inverted the second fraction instead of the first. They insisted, "That's just the rule!"

Applying the "Task Analysis Guide"

We realized that we needed to challenge the pre-service teachers to understand this "rule" and why it works. We needed a *next step, but deeper* task that supported and developed their understanding of the "big ideas" involved in dividing fractions.

We used the "Task Analysis Guide," a popular framework developed by Stein, Smith, Henningsen, and Silver (2009, see Table 1) to classify the cognitive demand of the "Sixths Task." We felt the task could be classified as either "procedures without connections" or as "procedures with connections," all depending on the level of cognitive demand. We conjectured that the task was likely to elicit the use of an algorithm; however, we did not know whether or not the pre-service teachers would connect the algorithm's procedures to the "big idea" of determining the whole and using fractions as operators. Stein et al. (2009) note that the task's level of cognitive demand also depends upon the mathematical thinking of the students who interact with it. In other words, the task may be of high level for one student but of low level for another. Therefore, when choosing a task it is important to *consider the characteristics of the task* as written as well as the *students' current conceptions* and *thinking* about the "big ideas" around which the task is focused (Stein et al., 2009). Although we were just getting to know these pre-service teachers and their mathematical thinking, we did conjecture that they came to us having always relied heavily upon procedural thinking about mathematics. We felt this task might help us assess their thinking about the traditional algorithm for the division of fractions.

Next Step, but Deeper: Task #2 with Pre-Service Teachers

In order to prompt Anna's and Janice's deeper investigation as to why "the rule" worked when dividing fractions, we designed a *next step, but deeper* task for them by adding some constraints to the problem. The "Sixths Task II" required them to solve the same problem again—but without using the algorithm. They were to only draw pictures to reveal and aid their thinking about the problem.

Low Cognitive Demand Tasks	High Cognitive Demand Tasks
Memorization– Tasks for which the goal is to increase the students' fluency in retrieving basic facts, definitions, and rules.	**Procedures with Connections–** Tasks that focus students' attention on the use of procedures for the purpose of developing deeper levels of understanding of mathematical concepts and ideas.
Procedures without Connections– Tasks that are algorithmic. Use of the procedure is either specifically called for or its use is evident based on prior instruction, experience, or placement of the task.	**Doing Mathematics–** Tasks that are non-routine in nature, are intended to explore a mathematical concept in depth, embody the complexities of real-life situations, or represent mathematical abstractions.

Table 1. "Task Analysis Guide" (Stein et al., 2009).

As the students worked together, Anna said, "We need to find out how many times 10/6 will go into 2/6." She realized it would not even do so one whole time, "It will be less than one whole—a fraction". After thinking a while, she then drew ten boxes and labeled her picture, writing "2/6" below the second box, and "10/6" below the last or tenth box (see Figure 2). She then realized that she could also "double label" her picture as tenths, beginning with 1/10, 2/10, 3/10, …10/10. She said that "one group of 2/6 was equivalent to 2/10" on her picture and came to the conclusion that "2/6 is 2/10 of 10/6."

In this example, Anna used her operation sense to rephrase the division computation problem as a more conceptual question: "How many times will 10/6 go into 2/6?" On one hand, we now recognize that Anna's reasoning while solving this problem was not especially efficient since the standard algorithmic procedure is often the fastest way to solve fraction division problems; on the other hand, we find it noteworthy that Anna was able to label a piece as being both 2/6 of 1 and 2/10 of 10/6. This "double labeling," we think, is an indication of reasoning with fractions in a powerful way.

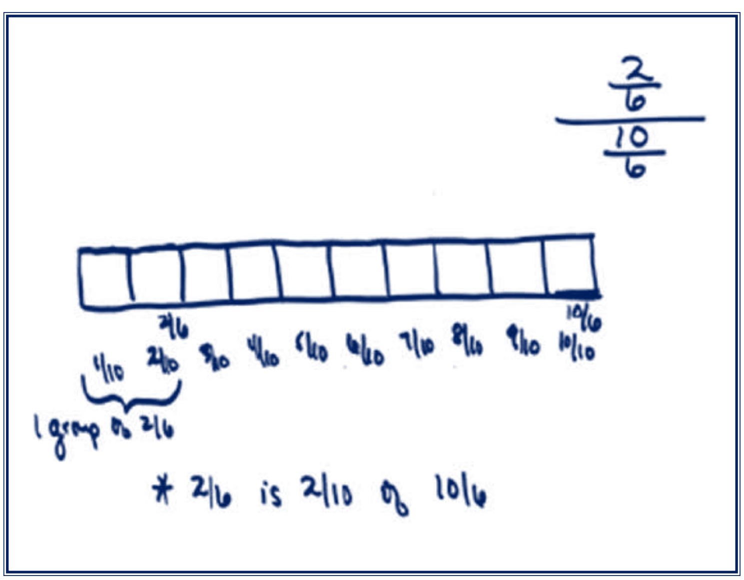

Figure 2. Anna and Janice, two pre-service elementary teachers, work to find the quotient of 2/6 divided by 10/6 without relying on the standard algorithmic procedure.

Guidelines for Designing Next Step, but Deeper Tasks

1. Begin with a research-based framework of the "big ideas" for the mathematical topic. Fosnot and Dolk (2002), for example, have detailed one framework for the big ideas of fractions, which they call the "landscape of learning." Big ideas within this particular framework include: the whole matters; equal (but not necessarily congruent) portioning; fractions as ratios or rates; fractions as division; fractions as operators with like numerators, as the denominator increases the faction's value decreases; equivalence; and finding and using common wholes to compare, add, or subtract fractions.

2. Design an initial task that, as written, is of potentially high cognitive demand and grounded in your students' current thinking. In other words, this task should be one about which many of your students have successfully constructed "ways of thinking" or even "steps for solving" due to the fact that they have most likely encountered a similar sort of problem multiple times previously.

3. Present the task to your students while making a concerted effort to keep the cognitive level high during implementation. Do not give them too many hints or do the thinking for them. Take note of the strategies that various students use as they work.

4. Design a *next step, but deeper* task or series of tasks based on students' work. The task(s) should allow students to confront the limits of their previous ways of operating, perhaps through the addition of new or different constraints or contexts.

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Implications for K-12 and University Mathematics Teachers

Next step, but deeper tasks are useful for both students and teachers. When teachers pose *next step, but deeper* tasks with constraints that push students to think beyond their familiar ways of operating, they encourage students to confront and construct understandings of concepts rather than just procedures. Furthermore, students are reminded that their teachers value and are interested in their mathematical thinking—not simply just their ability to obtain correct answers. This message in itself can be just as important as the mathematical content they are learning. Every time they are presented with and allowed to struggle with a *next step, but deeper* task, students are reminded that mathematics is about understanding the underlying structures of patterns and not merely identifying patterns or finding effective procedures to solve problems.

In addition to the benefits they offer our students as described above, these tasks serve us in several ways as teachers. First, they help us resist the temptation to quickly "move on" to the next topic the moment we see our students experience success in solving problems. Secondly, strategic follow-up tasks allow us to get as much "mileage" as we can out of a single problem's context. Prolonged engagement with a single type of problem increases the chance that students will truly engage in and remember the problems. They will be more likely, for example, to remember and refer to the "Sixths Task" in future discussions if it is one that they examined at least two different ways on separate occasions. Thirdly, by implementing *next step, but deeper* tasks, we as teachers are more likely to make appropriate inferences about what our students understand. We have more opportunities to attend to *how* our students are thinking, thus providing us with more data sources from which to make inferences. We are more likely to find the "limits" of our students' reasoning by finding problems that they can solve under some conditions but not others. Knowing these limits can inform our instruction so that we are more likely to teach effectively. Finally, designing these tasks and listening carefully to how our students are thinking about them engages us in reconstructing our own mathematical content knowledge. We join our students in the pursuit of constructing increasingly more connected, sophisticated, and conceptual understandings of the content we teach.

It is up to us as teachers to challenge both ourselves as problem posers and our students as problem solvers through *next step, but deeper* tasks. These tasks allow us to uncover our students'—as well as our own—often-fragile mathematical understandings that are typically based in procedures, and they also provide us with opportunities to support our students and ourselves in the development of deeper, more conceptual mathematical understandings.

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A Case for Elementary Mathematics Specialists in Indiana

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The time has come for elementary mathematics specialists in Indiana. The Association of Mathematics Teacher Educators (AMTE), the Association of State Supervisors of Mathematics (ASSM), the National Council of Supervisors of Mathematics (NCSM), and the National Council of Teachers of Mathematics (NCTM) recently released a joint position statement in which they recommend the use of elementary mathematics specialists (EMS) in preK–6 environments to "enhance the teaching, learning, and assessing of mathematics in order to improve student achievement." They advocate that every elementary school should have access to an EMS. The position statement also recommends that "districts, states or provinces, and institutions of higher education should work in collaboration to create (1) advanced certification for EMS professionals and (2) rigorous programs to prepare EMS professionals" (AMTE, ASSM, NCSM, & NCTM, 2010). In this article, we will discuss various issues surrounding the roles, certification, and preparation of EMS professionals in Indiana and other states.

Who are Elementary Mathematics Specialists?

An *elementary mathematics specialist* (EMS) is a teacher, teacher leader, or coach who possesses the special kind of knowledge and skill necessary to support effective mathematics instruction and student learning at the classroom, school, or district level. The specific roles and responsibilities of EMS professionals vary according to the needs and structure of each setting. The two most common EMS roles are the specialized teacher and the teacher leader or coach. Both of these models make productive use of the knowledge and skill of those special teachers who have profound understandings of mathematics, expertise in implementing—and helping others implement—effective practices, and abilities to support efforts that help all students learn important mathematics.

The *specialized teacher* works primarily with students. This EMS professional is responsible for teaching mathematics to all students in one or more grade levels or for providing remediation or enrichment for a particular group of students. The specialized teacher is able to focus on the development of students' mathematical understandings, while bringing a wealth of knowledge, skills, and resources to the effort.

The *teacher leader* or *coach* works primarily with other teachers, serving as a mentor to support changes in classroom practices or to provide professional development for colleagues in the areas of curriculum, teaching, learning, and assessment. This leader has a broad understanding of the many resources needed to support and facilitate effective instruction and professional growth.

The distinction between a *specialized teacher* and a *teacher leader* may be ambiguous. An elementary math specialist may sometimes engage in both roles. Regardless of whichever role the EMS plays, however, it sharply contrasts that of the elementary generalist who, as a result of teaching all core subjects, may find it difficult to develop the expertise they need to teach mathematics effectively.

Why Does Indiana Need Elementary Mathematics Specialists?

Throughout Indiana, as in most areas of the United States, elementary teachers are primarily generalists. Their pre-service teacher preparation typically includes two or three courses in mathematics content and one course in mathematics pedagogy. These courses are generally designed to develop pre-service teachers' understandings of the concepts underlying the mathematics they will teach and to introduce them to the fundamentals of mathematics teaching and learning. These courses, though, represent merely a small tip of the iceberg that constitutes the collective body of research and knowledge surrounding topics such as how children learn mathematics, effective strategies for teaching mathematics, learning trajectories for particular topics in the curriculum, relationships between standards and curricula, and authentic assessment of children's knowledge. Indeed, as Ball, Thames and Phelps (2008) found, the mathematical knowledge needed for teaching is multi-dimensional and involves aspects of both subject-matter knowledge and pedagogical content knowledge. In describing the knowledge that elementary teachers need, they state, "What seem most important are knowing and being able to use the mathematics required inside the work of teaching" (p. 404).

While many elementary teachers do pursue graduate education, few choose to take courses in mathematics or mathematics education. In 2011, for example, 46% of teachers of fourth-graders who took the mathematics portion of the National Assessment of Education Progress reported that the highest degree they hold is a Master's degree. Delving deeper into the data, only 2% of teachers reported that they had a major in mathematics or mathematics education during their graduate coursework; meanwhile, 37% of teachers reported they had a major in education—including either elementary or early childhood—during their graduate coursework (National Center for Education Statistics, 2011). Some teachers seek professional development to further their understanding of mathematics and mathematics pedagogy, but many teachers lack the opportunity, interest, passion, or courage to extend their expertise in the field. Yet, all of these elementary teachers continue to teach mathematics to children, and many of them lack the support needed to make significant improvements in their classroom practices.

What is the Special Expertise of Elementary Mathematics Specialists?

Regardless of the setting or responsibilities specific to them, elementary mathematics specialists need a deep, broad knowledge of mathematics content, expertise in implementing effective practices, and abilities to support efforts that help all students learn important mathematics. The Association of Mathematics Teacher Educators recently published a set of standards identifying the essential knowledge, skills, and dispositions EMS professionals need (AMTE, 2010). These standards not only include a focus on expertise in both content knowledge and pedagogical knowledge for teaching mathematics, but they also emphasize leadership knowledge and skills. For example, EMS professionals must understand learning trajectories related to particular topics such as fractions and place value. They must also design, select, and adapt worthwhile tasks to support particular learning goals and diagnose mathematical misconceptions and errors. They must use their leadership skills to improve mathematics programs at the school and district levels, as well as advocate for change at the state level.

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What is Being Done in Other States?

The following 13 states currently offer an EMS license, certificate, or endorsement: Arizona, California, Georgia, Idaho, Maryland, Michigan, North Carolina, Ohio, Oklahoma, South Dakota, Texas, Utah, and Virginia (Elementary Mathematics Specialists and Teacher Leaders Project, 2012). These programs vary in both certification requirements and job duties of the EMS.

Research is beginning to emerge to determine the effectiveness of various EMS models. In Virginia, researchers have begun to investigate the impact of elementary mathematics specialists. Through an NSF grant, a three-year randomized control study was undertaken that included grades 3, 4, and 5 and involved five school districts (Campbell & Malkus, 2010). There were 24 treatment and 12 control schools with a wide range of demographic and economic settings. The specialists were experienced classroom teachers selected by their school districts. They completed seven university courses in mathematics content, pedagogy and leadership to prepare for their new assignments. Data related to student achievement, teachers' beliefs about mathematics teaching and learning, and teachers' engagement in other forms of professional development were collected and analyzed. The study found that "elementary mathematics specialists had a significant positive impact on student achievement over time, but this effect only emerged as knowledgeable specialists gained experience and as schools' instructional and administrative staffs learned and worked together" (p. 25). As one would expect, the level of engagement between the EMSs and classroom teachers varied. The EMSs kept an electronic log of their activities and engagement with other teachers. The study found that those teachers highly engaged with the EMS showed significant changes in their beliefs about teaching and learning mathematics: they either increased in what the researchers called a "Making Sense" perspective or lowered in what they called a "Traditional" perspective. The study also examined whether or not the presence of an EMS would impact the engagement of teachers in other forms of professional development involving mathematics content and pedagogy. Findings showed that the presence of an EMS in a school did increase the likelihood of teachers engaging in such professional development.

What is Being Done in Indiana?

The State of Indiana currently does *not* offer an EMS license, certificate, or endorsement; and, because there is no official recognition of elementary teachers with specialized expertise in mathematics content, pedagogy, and leadership, there is no incentive for teachers to develop expertise in these areas. Furthermore, there are no guidelines for school districts to utilize that expertise.

Opportunities *do* exist in Indiana, though, for elementary teachers to develop the specialized expertise of an EMS. Ball State University, for example, has designed a set of mathematics content, pedagogy, and leadership classes and now offers a Master of Arts in Mathematics Education, complete with an option for elementary and middle school mathematics specialists. Consistent with the AMTE Standards, candidates for the program must hold a current middle school mathematics or elementary teaching license and have at least three years of middle school mathematics or elementary teaching experience. Recent discussions have focused on expanding this program to collaborate with partners from Indiana University, Purdue University, Purdue University Calumet, and the University of Southern Indiana.

As mathematics teacher educators, we pledge our support to the development of teachers' specialized knowledge for improving the mathematical learning of students. We encourage the identification of potential EMS candidates in Indiana, and we are prepared to assist in the training of those candidates. We recommend that Indiana offer an EMS license with initial and ongoing requirements aligned to the AMTE Standards. We also recommend that Indiana school districts look for powerful ways to utilize the expertise of EMS professionals.

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Making Projects Become Real Projects

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The purpose of this paper is to highlight two factors that have been successful when designing and implementing project-based learning (PBL) units. The first factor is structuring a unit's problem or challenge in such a way that students understand their role, the problem, and the expected outcome by carefully crafting a driving question. The second factor is involving relevant community partners as external evaluators for the projects. I will further discuss these two components below, and a sample PBL unit will later showcase the integration of these two elements.

In today's rapidly changing economy and tech-savvy industry, students need to actively construct their ideas and collaboratively engage in tasks that connect knowledge to the contexts of its application. Reform documents (National Council of Teachers of Mathematics [NCTM], 2000; National Governors Association and Council of Chief State School Officers, 2010) have emphasized the importance of understanding not only content but ways in which students engage themselves. Employers also encourage such teaching practices, and they ultimately seek graduates who can solve problems, exercise creativity, think critically, and communicate and collaborate effectively. These "soft skills" are imperative for jobs in the 21st century.

One way to exercise students' "soft skills" is by presenting them with real-world contexts and applications of these projects. Projects readily create a context and reason for students to learn and understand the related content. Unfortunately, many projects are designed to assess what students have learned at the conclusion of a chapter or unit. It is important to consider how teachers can design projects that serve as extensions of inquiry and problem solving rather than just as summative tools that assess whether or not students learned the specific content. This idea challenges the typical use of projects as end-of-unit culminating products. The stance I raise involves teachers creating projects around a driving question, or a realistic problem for students to solve; students can learn the intended content by being *pulled* through a driving question. Instruction is then carefully planned and integrated as students need more information to solve the problem. Markham, Larmer, & Ravitz (2003) describe this process as project-based learning and define it as "a systematic teaching method that engages students in learning knowledge and skills through an extended inquiry process structured around complex, authentic questions and carefully designed projects and tasks" (p. 4).

Author's note: *The PBL units showcased in this article were developed by University of Indianapolis Woodrow Wilson Teaching Fellows: Theodore Savich, Katherine Castro, and Crystal Collier.*

Krajcik and Blumenfeld (2006) describe the model's five key features:

1. The project or unit starts with a driving question that addresses authentic concerns in order to sustain students' interest during the project.
2. Students investigate the driving question through problem solving and, in the process, learn and apply important ideas specific to the discipline.
3. There is collaboration among students, teachers, and community members to find solutions to the driving question.
4. Completing projects often requires instructional, cognitive tools such as technology to enhance students' learning and ability to complete the project.
5. Students create tangible products that address the driving question and present them to their class and community members.

Thus, PBL instruction invites students to construct their own understandings by way of facilitator-orchestrated conversations that prompt them to explore complex connections and relationships among ideas.

PBL instruction is becoming more prevalent in Indiana schools. Schools that specialize in PBL instruction are called New Tech schools, and Indiana has become the national leader in state-wide New Tech implementation with more schools open and under development than any other state in the U.S. Indiana currently has 24 New Tech schools--more than any other state in the nation (University of Indianapolis, 2012). In addition, numerous schools not designated as New Tech are also implementing PBL practices for teaching mathematics. Thus, as many Indiana schools are pressing toward PBL as an instructional methodology, it is timely to support PBL practitioners throughout the state with practical strategies regarding the importance of a driving question and community partnerships.

Crafting the Driving Question

In order to design an effective driving question (DQ) for a PBL unit, first envision the end result: What standards can be coupled well to maximize students' learning? Projects should start with a vision that allows students to go through an extended process of inquiry in response to a complex question, problem, or challenge. A good driving question should allow students to investigate and solve a problem or challenge over a span of two to three weeks. Table 1 on the next page shows three criteria for how DQs can be provocative, open-ended, and discipline-centered.

Continued...

Making Projects Become Real Projects *Continued...*

Provocative DQ:	Open-ended DQ:	Discipline-centered DQ:
• Relates to a contemporary real world dilema. • Requires students to confront difficult issues in a field of study. • Involves current controversies and unknowns in studied subject. • Sustains student interest by relating to student-related topics and connecting to students' prior knowledge and local context. • Cannot be answered by typing DQ into a search engine (not "Google-able").	• Requires multiple perspectives. • Requires integration, synthesis, and critical evaluation. • Is feasible based on the evaluation of students' skills, time, and resources. • Requires students to identify patterns, themes, and principles of subject or subjects under study.	• Requires inductive and deductive reasoning. • Requires students to utilize and learn 21st Century skills. • Requires students to understand and apply knowledge around core standards.

Table 1. Criteria for crafting a driving question.

The DQ should ultimately hook students, clarify their roles, lay out the project or problem to be completed or solved, and provide clues for research questions. Table 2 lists several teacher-created driving questions that reflect the criteria mentioned above and include the standards intended to be taught.

Driving Question	CCSS-M and Mathematical Practices	Community Partner
How can we, as geometry students turned surveyors, investigate if our school is sinking using only the tools available in a geometry class to advise our administration?	• Understand that by similarity, side ratios in right triangles are properties of the angles in the triangle, leading to definitions of trigonometric ratios for acute angles. (G-SRT.6) • Explain and use the relationship between the sine and cosine of complementary angles. (G.SRT.7) • Use trigonometric ratios and the Pythagorean Theorem to solve right triangles in applied problems. (G.SRT.8) • Use geometric shapes, their measures, and their properties to describe objects. (G-MG.1) • Use appropriate tools strategically. • Attend to precision.	Professional land surveyor demonstrates the use of a total station, and students use it to check their data points. Students present their findings to the school administration and report whether or not the school is sinking.
Given limited materials and a fixed budget, how can we as landscapers apply the principles of polygonal area and perimeter to design a playground that maximizes Brookside Park's area so that it remains appealing to children and young adults?	• Derive, using similarity, the fact that the length of the arc intercepted by an angle is proportional to the radius; derive the formula for the area of a sector. (G-C.5) • Make formal geometric constructions with a variety of tools and methods. (G-CO.12) • Use coordinates to compute perimeters of polygons and areas of triangles and rectangles. (G-GPE.7) • Apply geometric methods to solve design problems (G-MG.3) • Use appropriate tools strategically.	Brookside's park manager and landscaping consultants introduce important aspects of the park. They also evaluate students' project designs.
How can we, as recent college graduates, determine the best vehicle purchase for our income in order to advise future clients?	• Create exponential equations in one variable and use them to solve problems. (A-CED.1.ii) • Use the properties of exponents to transform expressions for exponential functions. (A-SSE.3.c.iv) • Graph functions expressed symbolically and show key features of the graph, using technology for more complicated cases and by hand in simple cases. Graph exponential and logarithmic functions, showing intercepts. (F-IF.7.e) • Write a function defined by an expression in different but equivalent forms to reveal and explain different properties of the function. Use the properties of exponents to interpret expressions for exponential functions. (F-IF.8.b.ii) • Understand the inverse relationship between exponents and logarithms and use this relationship to solve problems involving logarithms and exponents. (F-BF.5) • For exponential models, express as a logarithm the solution to where a, c, and d are numbers and the base b is 2, 10, or; evaluate the logarithm using technology. (F-LE.4) • Model with mathematics.	Bankers recruit students to develop marketing materials that teach teens about financial choices specifically related to purchasing a vehicle. Banking associates provide a workshop on car loans, credit, and what it means to be financially responsible; they then later evaluate student-produced brochures.

Table 2. Sample PBL units with driving questions, standards, and community partners.

Involving Authentic Community Members

Involving community members in a PBL unit raises the bar for both students and teachers. Projects become extended processes of inquiry when students take on the role of helping community members solve a problem or question. Community partnerships allow students to create higher-quality authentic products and presentations because, in addition to earning a grade, they are servicing individuals who have specifically come to them with a problem that needs to be solved. In addition, such partnerships hold the teachers accountable because poor-quality products or presentations may reflect the quality of poor teaching. Nonetheless, having teachers, students, and members of the community come together to solve a problem or challenge for an extended period of time heightens the quality of work students would normally produce if they were only presenting to their teachers and peers. When students' products and presentations become open to public scrutiny and critique, the process in which students handle issues, debates, questions, or problems deepens.

Projects have the potential to be especially authentic when community partners and teachers collaboratively design them. The degree to which the community partners are involved within a PBL unit may vary—from simply evaluating the students' final products to providing workshops for students several times throughout the unit. If you are a PBL novice, include community members that are most easily accessible to you: parents, school administrators, and other classroom teachers. Gradually scale up and seek people in your community who could partner with your projects: university students and professors, government agencies, non-profit companies, and, ultimately, workers in technical fields. The driving questions listed in Table 2 align with their corresponding community partners and the brief descriptions of the roles within the specific PBL unit.

A Deeper Look into the "Is My School Sinking?" PBL Unit

A detailed look into the geometry PBL unit called "Is My School Sinking?" is showcased below. The project calendar in Table 3 shows a brief outline of how the unit unfolds. Note that the Common Core Mathematical Practices of using tools strategically (i.e., using the inclinometer, protractor, lab book, and total station equipment) and attending to precision (i.e., activities on days four, seven, nine, and eleven) are embedded within the unit. This PBL unit utilizes two types of community partnerships: a professional land surveyor and school administrators. A land surveyor is partnered with this PBL unit so students can see how the mathematics they learn is used in the real world. School administrators are included to encourage students to exercise 21st century skills.

Day 1	Launch the project by presenting the challenge to students (see Figure 1). Discuss expectations for successful project.
Day 2	Provide workshop on Pythagorean Theorem.
Day 3	Provide workshop on trigonometric functions: Sine-Cosine-Tangent and the sine and cosine of complimentary angles. Use exit ticket to assess students' knowledge (see Figure 2).
Day 4	Students build inclinometers. Provide workshop on reading a protractor and measuring tape, as needed. Readings must be precise! Discuss the difference between reading an inclinometer that uses a standard protractor versus the one students produced.
Day 5	Students collect first set of data points with inclinometers. Different groups survey different corners of the building. Talk about how to properly store the inclinometer.
Day 6	Quiz over Pythagorean Theorem (http://www.ictm.onefireplace.org/) and Trigonometric functions. Provide workshop on how to write the first set of data points in the lab book.
Day 7	Discuss first set of data points. How could we improve data collection and analysis? Check-in: Is the lab book complete with drawings, data points, and data analysis from Day 5?
Day 8	Students collect second set of data points with inclinometers.
Day 9	Check-in: Is the lab book complete with drawings, data points, and data analysis from Day 8? Professional land surveyor visits classroom to describe what her job entails and demonstrates the use of a total station. Students use it to check the accuracy of their data points.
Day 10	Students practice presentations and finalize drawings.
Day 11	Students present their findings on whether or not the school is sinking to school administrative staff. Presentations must include drawings from the lab books, how they changed procedures from the first data set to the second data set, and why those changes result in improved data collection and analysis.
Day 12	Exam over sine, cosine, and tangent. Show and Tell: An app that allows one to use a smart phone as inclinometer. Reflect on the PBL Unit. Distribute the End-of-Project Self-Assessment Worksheet (http://www.ictm.onefireplace.org/).

Table 3. Project calendar of "Is My School Sinking?" PBL unit.

Continued...

Dear Geometry Students,

Have you ever noticed that every day you come to school, it seems like the building has sunk just a little bit lower than the day before? Our best guess in the office is that either the school was built on a sinkhole, or that the builders did not take the weight of the books, computers, and furniture into account when they built the building.

We plan on hiring professional land surveyors to determine whether or not the building is sinking, but we can only afford to hire them to measure one corner of the building. That's why we are asking the geometry students to use protractors, string, weights, and a 20ft tape to determine the height of each corner of the buildings on campus. Safety, of course, dictates that you will not be allowed access to the roof, and because the height of the building is greater than 20ft, you will not be able to use the tape to directly measure the height of the building. It is up to you to determine the most accurate way to determine height, but your results will be judged against the professional results. The original architectural plans are available to compare the original height of the building and the current height.

Each group of students will present their findings to us, making sure to explain your process and conclusions, especially the ways that you improved your methods over time to achieve the most accurate conclusions. Your teacher will help you get the equipment set up and teach you about right triangle trigonometry, but it is up to you to come up with an answer to this question: How can we as geometry students turned surveyors, investigate if our school is sinking, using only the tools available in a geometry class to advise our administration?

Sincerely,

Your concerned administration.

Figure 1. Letter to launch the project.

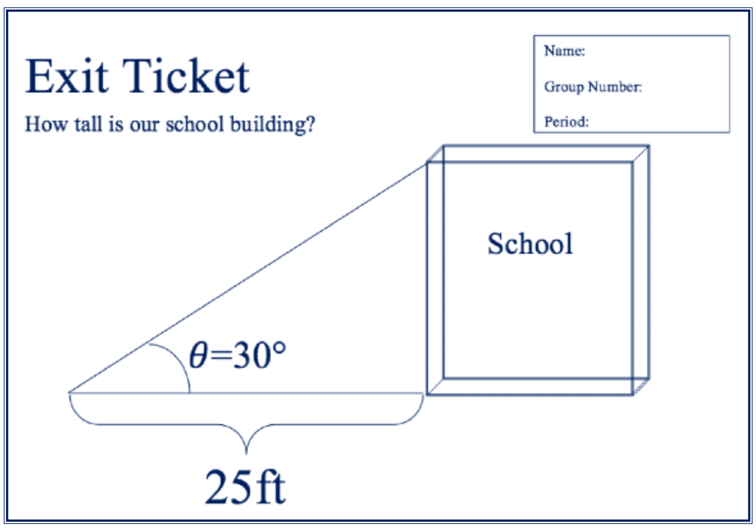

Figure 2. Exit ticket on Trigonometric Ratios.

Summary

PBL units in mathematics classrooms can become relevant and authentic experiences for both teachers and students. Teachers scaffold content and activities in order to guide the learning process through a driving question. In addition, students actively construct knowledge in collaborative groups over an extended period of time to assist community partners. Posing provocative, open-ended driving questions and incorporating community partnerships are ways to make projects come to life.

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Indiana's Common Core Mathematics:
What does it mean for you?

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The transition to Indiana's Common Core Standards (INCC) for Mathematics began in 2010 with Indiana's adoption of the Common Core Standards for Mathematics. Kindergarten and Grade 1 teachers have already begun their implementation of INCC and have found the transition to be both rewarding and challenging, and over the next two years, districts will implement INCC in all K–12 math classrooms in anticipation of the expected next generation assessments in 2014–15. Some districts have already begun their implementation in Grades 2–12; others are exploring what the transition will mean in their classrooms. Regardless of where you are in the transition process, there are several crucial elements of INCC and the anticipated new assessments that can help you answer the question: "What does this mean for me and my students?"

INCC Grade Level Content Shifts

In INCC, grade-level content may shift to lower grade levels from where it was found in the Indiana Academic Standards. Some shifts require brand new content to be taught at a grade level, while others equate to an extension of the current Indiana Academic Standard (IAS) either through extending the current standards to require a deeper understanding at a particular grade or through an integration of the Standards for Mathematical Practice. INCC content is designed in 'progressions' rather than in 'strands' as the current IAS are organized. An example of this redesign in INCC can be captured in the discussion of fractions. In the current IAS, our students begin learning the concept of fractions in Kindergarten when we introduce the idea of dividing a whole into equal parts. We continue teaching this fraction 'strand' throughout Grades 1–8 by building on the concept of a fraction as parts of a whole and continue with operations with fractions through 8th grade. In INCC, the Fraction Progression spans only Grades 3–5. Although we may discuss fractions in Grades K–2, the actual conceptual understanding and operations with fractions begins and ends between grades 3–5. By Grade 5, students should have mastered fractions. As a result, students in Grades 6–8 are using fractions in expressions, equations, and contextual problems. The implementation of INCC in grades 6–8 removes the time spent reviewing fractions each year. This is just one example of the content shifts that occur with the implementation of INCC.

INCC Instructional Shifts

The instructional shifts that occur in the implementation to INCC are perhaps the most profound changes that students and teachers will experience. Three major shifts should occur in an INCC classroom, which ideally will dictate the professional development that teachers are provided as part of their preparation for this transition.

Focus:

Focus is one of the most exciting aspects of the Instructional Shifts for teachers. Finally, teachers can significantly narrow the scope of content and deepen how time and energy is spent. No longer do teachers have to teach the content that is 'a mile wide and an inch deep.' They have the opportunity to focus deeply only on what is emphasized in the standards, so that students gain strong foundations in the areas essential for college and career readiness. Focus allows students to deeply understand the mathematics, to fluently use the procedures, and to confidently apply the mathematics they know inside and outside the classroom.

Coherence:

INCC Standards are designed around coherent progressions as described earlier. Teachers are able to connect the learning across grade levels to build new understanding from foundations built in previous grades. Teachers can begin to count on the students' foundational knowledge rather than the need to spend instructional time reviewing content from previous grades. Content within grade levels is also explicitly connected to other content, which adds additional structure and support to the standards document. By linking the major content together in content progressions both within and across grades, students experience a flow to their mathematics instruction throughout grades K–12.

Rigor:

INCC use a three-pronged approach to rigor: conceptual understanding, procedural skill and fluency, and application. Students should access concepts from a number of perspectives in order to see the math more than as a memorization of formulas and procedures. The standards call for speed and accuracy in calculation to remove the barriers to conceptual understanding and application. Several opportunities should be provided for students to apply math to contextual problems where students can find math structures in the context and make meaning of the context.

Partnership for Assessment of Readiness for College and Careers (PARCC)

The PARCC assessments are expected to be fully operational in the 2014–15 school year. The assessments will model the mathematics shifts called for in the Standards. The assessments will **focus** on the key topics outlined in the PARCC Model Content Frameworks; the assessments will be mindful of **coherence**, understanding how math topics progress and fit together; and the assessments will have **rigor**, being mindful to have balance with conceptual understanding,

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Indiana's Common Core Mathematics Continued...

procedural skill and fluency, and application. The Standards for attention to Mathematical Practices, in connection with content, will also play a major role in assessment items with an emphasis placed on reasoning, precision, and modeling. Resources to be aware of are listed below.

Description of Resource	Web page Address
PARCC sample tasks just released and the **PARCC Model Content Frameworks** which includes information about Major, Additional and Supporting Clusters at each grade level. The Major Clusters will likely make up approximately 70% of the assessments. The frameworks also contain information about how standards connect (coherence), how the practices connect with content, and more.	http://parcconline.org/
Other sample tasks aligned to the Common Core State Standards.	http://illustrativemathematics.org/
Recorded WebEx sessions on the **PARCC Model Content Frameworks** and **Standards for Mathematical Practice** can be found in the IDOE—Assessment Information for Teachers Learning Community on the Learning Connection	https://learningconnection.doe.in.gov/UserGroup/GroupDetail.aspx?gid=649
Instructional and Assessment Guidance Documents for Grades 3-8 for the 2012-13 school year.	http://www.doe.in.gov/achievement/assessment/istep-grades-3-8

Transition to Indiana's Common Core Standards and the anticipated PARCC assessments will provide our teachers and students an opportunity to raise the bar in mathematics. Students will be asked to reach a level of mathematical understanding that assists them in reaching college and career readiness which enable students to become life-long learners.