Seventh Grade Mathematics: Incorporating Authentic Learning into Measurement

by

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Abstract

Students in the United States continue to have major difficulties with concepts of measurement as shown by student scores on standardized tests. It is important for students to have hands-on measurement experiences in contexts outside of the mathematics classroom, with a focus on student understanding of the fundamental concepts of measurement, as opposed to simply applying formulas. This research project provided three long-term measurement units for possible use by middle school teachers in their classroom. The units integrated culminating student projects that involve authentic learning experiences and connections to other disciplines. The three student projects incorporate measurement with art, architecture, chemistry, business, and language arts. These interdisciplinary connections were designed to help students appreciate the usefulness and significance of mathematics. In addition to the student projects the units contain lesson plan outlines and teacher notes. Another distinctive component of the research project is the International Baccalaureate (IB) Middle Years Programme (MYP) unit planner which explains how the units fit within the IB MYP framework.
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Introduction

Students in the United States continue to have major difficulties with concepts of measurement as shown by student scores on standardized tests. On the 2007 Trends in International Mathematics and Science Study (TIMMS), the only content domain where U.S. eighth graders scored below the mean scale score included geometric shapes, geometric measurement, and location and movement (Gonzales, Williams & Jocelyn, 2009). Additionally, measurement was the lowest scoring objective on state level standardized exams (TEA, 2009).

Not only is measurement an essential foundation for much of mathematics, it also has more real-world applications than other mathematical domains (Preston & Thompson, 2004). Planning, problem solving, communicating, and decision making are important in life and all aspects of mathematics, but they should be emphasized even more with measurement because of the real-world nature of the topic. It is important to take steps to improve student understanding in this vital area of mathematics.

The International Baccalaureate (IB) program, established in 1965, emphasizes international understanding and a rigorous curriculum for elementary, middle, and highschool students. The IB curriculum supports already existing curriculum by providing students with knowledge, critical-thinking skills and an international awareness (Tookey, 2000). The Middle Years Programme (MYP, 2009) for IB integrates disciplines in order to present a holistic and interrelated approach to learning. One of the benefits for teachers belonging to an IB school is the availability of online IB resources found on the Online
Curriculum Center (OCC) website. On this site teachers can find such resources as unit plans, lesson plans and assessments. However, the OCC is currently lacking material on middle school measurement.

The purpose of this research project was to produce three authentic, integrated International Baccalaureate (IB) units focused on seventh-grade measurement concepts to be used by Texas middle school teachers. The three units are titled Geometric Window Art, Cereal Container, and Tetrahedral Kite. The units contain hands-on activities and experiences that are crucial to understanding measurement. The culminating student projects for these units serve as an authentic way for students to demonstrate and apply their knowledge of measurement. All three units encourage students to formulate mathematical connections to other disciplines and will be based on the IB Middle Years Programme (MYP, 2009) fundamental concepts of holistic learning, intercultural awareness, and communication.

The guiding principles for this project were:

1. Learning measurement is difficult;
2. Having students do authentic and meaningful activities increases their understanding of measurement and thereby increases their scores.
3. Measurement activities are best done in the context of other disciplines.
4. Students go through levels of understanding of measurement and a given student’s level is observable through his/her work.
Literature Review

On the 2007 Trends in International Mathematics and Science Study (TIMMS), U.S. eighth-graders’ average scores in geometry were lower than the mean scale score by twenty points (Gonzales, Williams & Jocelyn, 2009). The TIMSS mathematics scale ranges from 0 to 1,000 with the international mean score set at 500, and a standard deviation of 100.

In Texas, the average 2009 Texas Assessment of Knowledge and Skills (TAKS) scores for middle school mathematics showed measurement as the weakest mathematical concept for middle school students. For seventh grade students, the average percent of items correct on the measurement objective was 67%; this was the lowest percent of the six TAKS objectives for seventh grade mathematics (TEA, 2009).

Assessments like the 2007 TIMMS and 2009 TAKS indicate student understanding of measurement as a weakness for middle school students. Similar results are found on previous TIMMS data. For instance, the 1999 TIMMS revealed how U.S. students scored the lowest on measurement items, in particular unit conversions and calculations of volume, circumference, and estimation (Wilson & Blank, 1999).

Why is measurement so difficult for U.S. middle school students? Some teachers have pointed to the confusion that can result from having two different systems of measurement, metric and customary. Students have probably developed a weak understanding of both, as opposed to learning the metric system well (Thompson & Preston, 2004). Other literature on this subject has
indicated that one of the central reasons middle school students have difficulty with measurement is due to the emphasis on doing routine procedures such as substituting numbers into formulas as opposed to developing conceptual understanding (Wilson & Blank, 1999). It may be easier for a teacher to give a worksheet with pictures of objects and given measurements because of available resources and time, rather than providing students an opportunity to engage in complex problem solving. Students are then deprived of the opportunity to consider what attribute to measure, to select an appropriate unit and measurement tool, and to understand formulas and how they work (Martinie, 2004).

One strategy that could help alleviate the difficulty students have with measurement is to approach the concept with authentic activities, or project-based learning. "Project based learning is an instructional approach built upon authentic learning activities that engage student interest and motivation" (Project Based Learning, 2007, p. 1). A growing body of academic research supports the use of project-based learning. Boaler (1998) concluded that using mathematical procedures within authentic activities allowed the students to appreciate the procedures as tools they could use and adapt. Authentic activities led to increased understanding of mathematics and the ability to transfer this knowledge to different situations. There is also evidence that project-based learning is an effective method for teaching skills such as planning, problem solving, communicating, and decision making (Thomas, 2000).
Another approach that would assist students in gaining a meaningful understanding of measurement is connecting or integrating the learning of measurement with other disciplines. Kepner (2009) stated, “When students connect mathematical ideas, their understanding becomes deeper and more lasting, and learners come to view mathematics as a coherent whole – connected with other subjects and their own interests and experiences” (p. 1). Heibert and colleagues (2003) found support for the same idea in research on the TIMMS. Mathematics classrooms that score high on international comparisons of mathematics achievement all have something in common – they teach their students to build mathematical connections and conceptual understanding through complex problems. Since measurement arguably provided more connections than other mathematical strands, it is not only easier to integrate with other content strands and subject areas, but also offers promise for increasing students' understanding and skill in measurement (Preston & Thomson, 2004). A cross-disciplinary application of mathematics can help students appreciate how mathematical knowledge can broaden comprehensive understanding in other subject areas (Stump, Clark, Mitchell, & Roebuck, 2008).

Levels of Knowledge in Measurement

Battista (2004) has stated, “Selecting/creating instructional tasks, adapting instruction to students' needs, and assessing students’ learning progress require detailed, cognition-based knowledge of how students construct meaning for the specific mathematical topics targeted by instruction” (p. 188). In other words, to
implement meaningful mathematical instruction, it becomes necessary to first understand the ways that students learn measurement. Second, it is important to be able to monitor and gauge their level of knowledge and reasoning with measurement concepts.

There are three critical components of an assessment system for understanding the development of a student's mathematical reasoning. The first is identification of core ideas. Some examples of core ideas are perimeter and area. The second component is a conceptual framework for understanding students' reasoning about the ideas. The descriptions for the conceptual framework include levels of sophistication that students go through in moving from intuitive ideas to ideal states of learning. It also includes cognitive obstacles and misconceptions that students face in learning measurement. The third component is a coherent set of assessment tasks. These tasks enable teachers to investigate student understanding and to locate a student's position in constructive routes typically taken in acquiring proficiency with measurement (Battista, 2004). The student assessment tasks for this research project were developed using the three critical components of an assessment system in order to effectively support student learning of measurement.

Backwards Design Model

The backwards design model centers on the idea that the design process should begin with identifying the desired results and then "work backwards" to develop instruction; rather than the traditional approach which is to define what
topics need to be covered. The Wiggins and McTighe (2001) framework identifies three main stages:

- Stage 1: Identify desired outcomes and results
- Stage 2: Determine what constitutes acceptable evidence of competency in the outcomes and results (assessment)
- Stage 3: Plan instructional strategies and learning experiences that bring students to these competency levels
Results

This project has focused on the philosophy that measurement is difficult for students to learn and understand and that authentic project-based and integrated learning of mathematics improves knowledge and understanding of measurement, thus increasing scores in this area. In addition, it serves as a resource for IB middle school teachers.

Following the method of backward design (Wiggins & McTighe, 2001), summative and formative assessments for the three units on measurement were created first. The desired results, or goals, for student understanding of measurement were identified. Then acceptable evidence of these desired results were determined. Last, the learning experiences and instruction were planned.

The assessments were designed to check for the different levels of understanding in measurement based on Battista’s (2004) framework. The summative assessments consist of three student projects with task-specific rubrics (Dodge, 2001) or IB rubrics (MYP, 2009) and were designed to engage students in measurement experiences that promote a conceptual understanding. The formative assessments consist of teacher-led class discussions and observations of student work and group discussions.

The first student project is Geometric Window Art. It was created and piloted by the author during the previous school year; however it needed to be enhanced and documented. Improvements were made to the art design instructions, design requirements, and instructions for the booklet, such as having students measure in both customary and metric units. The teacher notes,
lesson plan outline, and MYP unit planner still needed to be produced to coincide with this student project.

The Cereal Container student project originated from the desire to have a unit that focused more on surface area and volume. This student project has the students build a container that is not necessarily a box. It is interconnected with statistics, marketing and language arts.

The last student project is the Tetrahedral Kite. This is a fairly popular and well-known student project (Mabbott, 2005). The author had been introduced to it in a graduate class and at a professional development conference. The reason this was used as the third student project was due to the fact that it could be enhanced and built to correspond with the IB requirements. It was created with the author's students in mind, however, the detailed description should easily allow for use by other teachers.

The next step was the creation of lesson plan outlines and teacher notes to accompany each student project. Each lesson plan outline lists the prerequisite concepts that should be taught prior to each of the student project assessments. The outline contains two essential components: the objectives for each lesson and a recommended sequence for the lessons in the unit. The teacher notes serve as guidance for teachers prior to, during, and after the completion of each unit. The teacher notes include the materials and time needed for the measurement units.

The final step was completing the MYP unit planner for IB. To bring together the written, assessed and taught curriculums with the principles of the
program in mind, the MYP has designed a planning tool for teachers to use when designing MYP units of work. The MYP unit planner can be found in Appendix A. In the MYP, all teaching and learning is planned through MYP units of work. Each of these units should stand alone as a significant, engaging, relevant and challenging learning experience, be driven by a unit question that is conceptually based, and require students to reflect on their learning and encourage them to engage in responsible action (MYP, 2008).
Conclusion

The outcome of this research project was three well-designed measurement units that can serve as helpful resources to be used in the middle school mathematics classroom. The components of the measurement units, including the lesson plan outlines and the hands-on student projects, will be used in the author's classroom. The units are consistent with Boaler's (1998) project-based learning. In addition, interdisciplinary connections are woven within the units as promoted by Stump (2008).

All three measurement units can found on a CD and contain the following elements.

- Geometric Window Art Unit
  - Teacher notes
  - Lesson outlines
  - MYP unit planner
  - Student handouts with rubric

- Cereal Container Unit
  - Teacher notes
  - Lesson outlines
  - MYP unit planner
  - Student handouts with rubric

- Tetrahedral Kite Unit
  - Teacher notes
  - Lesson outlines
  - MYP unit planner
  - Student handouts with rubric

There are multiple benefits from this research project. Due to the meticulous development of these units, students will receive more insightful instruction on measurement concepts. Another benefit is that the measurement units can be used in their entirety, or in individual components. The three
measurement units will also be shared online through the Online Curriculum Center (OCC) with other IB teachers. This will help fill the void in IB MYP measurement resources.

This research project provides valuable resources for student improvement in a highly needed area of mathematics and will be shared locally and with IB teachers around the world. Eventually, it will also be posted on the Texas A&M University-Corpus Christi mathematics graduate website.
REFERENCES


