Seventh Grade Mathematics: Incorporating Authentic Learning into Measurement

A PROPOSAL for a PROJECT in MATHEMATICS

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Abstract

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 provides three long-term measurement units for use by middle school teachers in their classroom. The units integrate culminating student projects that involve authentic learning experiences and connections to other disciplines. The three student projects will incorporate measurement with art, architecture, chemistry, business, and language arts. These interdisciplinary connections are designed to help students appreciate the usefulness and significance of mathematics. In addition to the student projects the units will contain lesson plans, hands on activities, worksheets, teacher notes, and formative/summative assessments. 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.
Introduction

Students in the United States continue to have major difficulties with concepts of measurement as shown by student scores on standardized tests. For example, in the 2007 Trends in International Mathematics and Science Study (TIMMS), US eighth-graders' average scores in geometry was lower than the TIMMS scale score average by twenty scale score points (Gonzales, Williams & Jocelyn, 2009). The three topic areas in geometry are geometric shapes, geometric measurement, and location and movement. The TIMSS mathematics scale ranges from zero to 1,000 with the international mean score set at 500, and a standard deviation of 100. This was the only content domain where the US average was below the TIMMS scale score. In Texas, the average middle school 2009 Texas Assessment of Knowledge and Skills (TAKS) scores also reflect the same point; measurement is the weakest mathematical concept for middle school students. For all seventh grade students administered the 2009 TAKS test, the average percent of items correct on the measurement objective was 67% and this was the lowest percent out of the six TAKS objectives (Texas Education Agency, 2009).

Not only is measurement an essential foundation for much of mathematics, it also has more real-world applications than most other mathematical domains (Preston & Thompson, 2004). It is important to take steps to improve student understanding in this vital area of mathematics.

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

The guiding principles for this project are as follows:

1. Learning measurement is difficult.
2. Having students do authentic and meaningful activities will increase their understanding of measurement and thereby increase 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.

Related Work and Justification

Assessments like the 2007 TIMMS and 2009 TAKS indicate student understanding of measurement as a weakness for middle school students. Similar results can be found from previous TIMMS data. For instance the 1999 TIMMS revealed how US students scored the lowest on measurement items, in particular unit conversions and calculations of volume, circumference, and estimation (Wilson & Blank, 1999). This project will focus on the philosophy that measurement is difficult for students to learn and understand and that authentic
project-based and integrated learning of mathematics will improve knowledge and understanding of measurement, thus increasing scores in this area. In addition, it will serve as a resource for IB middle school teachers.

Why is measurement so difficult for US middle school students? Some teachers point to the confusion that can result from having two different systems of measurement, metric and customary. Students probably develop a weak understanding of both, as opposed to learning the metric system well (Thompson & Preston, 2004). Other literature on this subject indicate 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 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 would 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 lead 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). These skills 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.

Another approach that would assist in students gaining a meaningful understanding of measurement is by connecting or integrating the learning of measurement with other disciplines. This was best stated by NCTM president Hank Kepner (2009), "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 in research on TIMMS found support for the same idea. 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 (Heibert, 2003). Since measurement arguably provides more connections than other mathematical strands, it not only would be easy to integrate it with other content strands and subject areas, but it 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, 2008).

Levels of Knowledge in Measurement

Battista (2004) states, "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 in measurement it is necessary to understand the way students learn measurement and be able to monitor and measure 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 coherent sets of assessment tasks. These tasks enable educators to investigate student understanding and 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 will be
developed using the three critical components of an assessment system in order to effectively support student learning of measurement.

International Baccalaureate Program

The International Baccalaureate (IB) program, established in 1965, emphasizes international understanding and a rigorous curriculum for elementary, middle, and high-school students. The IB curriculum supports already existing curriculum by providing students with knowledge, critical-thinking skills and an international awareness (Tooke, 2000). The Middle Years Programme (MYP) 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. This research project will be shared with other IB teachers around the world and also serve to improve measurement locally.

This research project is worthy of a master's degree in mathematics because it provides valuable resources for student improvement in a highly needed area of mathematics. This research project also applies knowledge acquired from graduate coursework such as the Assessment, Geometry and Measurement, Problem Solving, and two Modeling Courses. The knowledge obtained from these courses helped provide sources for research, creation of the lessons and assessments, and an in depth understanding of measurement.
Planned Actions

The first step of the research project is a literature review on related works. A wide-range of literature is required to support the philosophies on which the research project is built. This literature should come in the form of credible books, research articles, and journal articles.

The second step in the research project is designing the summative and formative assessments for the three units on measurement. First, the desired results, or goals for student understanding of measurement will be identified. Then the acceptable evidence of these desired results to be used in the student assessments will be determined. Last, the learning experiences and instruction will be planned. This process will lead to better student performance and is known as backwards design (Wiggins & McTighe, 2001). These assessments will be designed to check for the different levels of understanding in measurement based on Battista’s framework (2004). The summative assessments will consist of three student projects with task-specific rubrics (Dodge, 2001), IB rubrics (MYP, 2009), as well as quizzes with short-answer questions. The formative assessments will consist of teacher-led class discussions and observations of student work and group discussions.

The third step is the creation of lesson plans, teacher notes that will accompany the lesson plans, hands-on activities, and homework worksheets. The lesson plans will contain many essential components such as objectives, materials, procedures, modifications, extensions and so forth. A lesson plan outline is included in Appendix A with descriptions of the key components of a
lesson plan (TAMU, 2009). The hands-on activities will be designed to engage students in measurement experiences that promote a conceptual understanding of the concepts. Finally, the homework worksheets will be prepared for student practice with the lesson concepts and will enhance the lesson objectives.

The final step is 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 B. 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).

**Timeline**

<table>
<thead>
<tr>
<th>Month</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>September - October 2009</td>
<td>Literature review and proposal outline</td>
</tr>
<tr>
<td>November 2009</td>
<td>Write, edit and revise proposal</td>
</tr>
<tr>
<td>December 2009</td>
<td>Defend proposal</td>
</tr>
<tr>
<td>January 2010</td>
<td>Write summative/formative assessments, project requirements and rubrics</td>
</tr>
<tr>
<td>February 2010</td>
<td>Create lesson plans, teacher notes, activities and worksheets</td>
</tr>
<tr>
<td>March 2010</td>
<td>Complete IB MYP unit planner</td>
</tr>
<tr>
<td>April 2010</td>
<td>Final revisions of the project and submission of the final draft manuscript to committee</td>
</tr>
<tr>
<td>May 2010</td>
<td>Defend project and deliver copies of project manuscript</td>
</tr>
</tbody>
</table>
End Results Intended

The outcome of this research project will be three well-designed measurement units that will serve as helpful resources to be used in the middle school mathematics classroom. The components of the measurement units, including lesson plans, student activities, projects and assessments, will be used in the author's classroom. Due to the meticulous development of these units, students will receive more insightful instruction on measurement concepts. The three measurement units will also be shared online through the OCC with other IB teachers. This will help fill the void in IB MYP measurement resources. Eventually, the research project may also be posted on the Texas A&M University-Corpus Christi mathematics graduate website. The measurement units can be used in their entirety or in individual components.


Appendix A

Lesson Plan Components

Objectives:
- Write in specific terms
- State what you want students to know or be able to do by the end of the lesson.

TEKS: List the TEKS that are covered by the lesson.

Materials:
List all materials that will be needed for the lesson. Be sure materials are ready ahead of time. Examples: textbook, reference materials, technology, art, music, lab equipment, URLs, CDs, videos.

Motivation:
Use pictures, brainstorming, real objects, thought-provoking questions, riddles, poems, books, games, personal experiences, experiments, disappointing events, etc., to focus students on what is to be learned.

Teaching Procedure (Label Guided Practice and Independent Practice):
- Produce a step by step plan of how you will teach the objective
- State clearly the lesson objective; relate to prior learning
- Give a purpose — (Tell students why it is important to learn this and how it will help them in the future)
- Present new information and relate it to existing knowledge of students, including misconceptions
- Model examples of the new skills and demonstrate to the student exactly what they are to do (include visuals whenever possible)
- Recap important points often
- Question throughout to check for understanding
- Include sample question, remember to include higher level/critical thinking questioning
- Involve the students throughout the lesson
- Include guided (completed with teacher’s assistance) and independent activities (without teacher’s assistance) that reinforce the lesson objective (label these activities with GP and/or IP)
- Monitor student responses to assess students’ needs

Closure:
- Recap the main points by referring back to the objective
- Keep closure student-centered (What did you learn today? Why did you learn it? How will it help you?)
- Ask questions that will give you feedback on student mastery of the lesson objective
- Relate to future learning

Lesson Extension and/or Modification:
- Provide extension activities for those who have mastered the objective
- Provide remediation for those who did not master the objective

Assessment of Learning:
- Ask yourself, “How will I measure to see if learning has occurred?” This may be accomplished through observation of specific work habits, worksheets, group projects, tests, oral discussions, illustrations, etc.
- You may place self-evaluations on the back. (What were the strengths of this lesson? What needed to be changed? Write teaching this lesson I learned … )
**Appendix B**

**MYP unit planner**

<table>
<thead>
<tr>
<th><strong>Unit title</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher(s)</td>
<td></td>
</tr>
<tr>
<td>Subject and grade level</td>
<td></td>
</tr>
<tr>
<td>Time frame and duration</td>
<td></td>
</tr>
</tbody>
</table>

**Stage 1: Integrate significant concept, area of interaction and unit question**

<table>
<thead>
<tr>
<th><strong>Area of interaction focus</strong></th>
<th><strong>Significant concept(s)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Which area of interaction will be our focus?</td>
<td>What are the big ideas? What do we want our students to retain for years into the future?</td>
</tr>
<tr>
<td>Why have we chosen this?</td>
<td></td>
</tr>
</tbody>
</table>

| **MYP unit question** |  |

**Assessment**

What task(s) will allow students the opportunity to respond to the unit question?

What will constitute acceptable evidence of understanding? How will students show what they have understood?

Which specific MYP objectives will be addressed during this unit?
Stage 2: Backward planning: from the assessment to the learning activities through inquiry

Content
What knowledge and/or skills (from the course overview) are going to be used to enable the student to respond to the unit question?
What (if any) state, provincial, district, or local standards/skills are to be addressed? How can they be unpacked to develop the significant concept(s) for stage 1?

Approaches to learning
How will this unit contribute to the overall development of subject-specific and general approaches to learning skills?

<table>
<thead>
<tr>
<th>Learning experiences</th>
<th>Teaching strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>How will students know what is expected of them? Will they see examples, rubrics, templates?</td>
<td>How will we use formative assessment to give students feedback during the unit?</td>
</tr>
<tr>
<td>How will students acquire the knowledge and practice the skills required? How will they practice applying these?</td>
<td>What different teaching methodologies will we employ?</td>
</tr>
<tr>
<td>Do the students have enough prior knowledge? How will we know?</td>
<td>How are we differentiating teaching and learning for all? How have we made provision for those learning in a language other than their mother tongue? How have we considered those with special educational needs?</td>
</tr>
</tbody>
</table>
### Resources

What resources are available to us?

How will our classroom environment, local environment and/or the community be used to facilitate students' experiences during the unit?

### Ongoing reflections and evaluation

In keeping an ongoing record, consider the following questions. There are further stimulus questions at the end of the "Planning for teaching and learning" section of MYP: From principles into practice.

#### Students and teachers

- What did we find compelling? Were our disciplinary knowledge/skills challenged in any way?
- What inquiries arose during the learning? What, if any, extension activities arose?
- How did we reflect—both on the unit and on our own learning?
- Which attributes of the learner profile were encouraged through this unit? What opportunities were there for student-initiated action?

#### Possible connections

- How successful was the collaboration with other teachers within my subject group and from other subject groups?
- What interdisciplinary understandings were or could be forged through collaboration with other subjects?

#### Assessment

- Were students able to demonstrate their learning?
- How did the assessment tasks allow students to demonstrate the learning objectives identified for this unit? How did I make sure students were invited to achieve at all levels of the criteria descriptors?
- Are we prepared for the next stage?

#### Data collection

- How did we decide on the data to collect? Was it useful?