Perspectives and Practices of Elementary Teachers Using an Internet-Based Formative Assessment Tool: The Case of *Assessing Mathematics Concepts*

By Christie S Martin[1], Drew Polly[2], Chuang Wang[3], Richard G Lambert[3] and David K Pugalee[4]

[1]Univ of South Carolina, College of Education, Dept. of Teaching and Instruction, Wardlaw College, Columbia, SC, USA,:
[2]UNC Charlotte, Dept of Reading and Elementary Education, College of Education, 9201 University City Blvd. Charlotte, NC
[3]UNC Charlotte, Dept of Educational Leadership, College of Education, 9201 University City Blvd. Charlotte, NC 28223
[4]UNC Charlotte, Center for STEM Education , College of Education, 9201 University City Blvd. Charlotte, NC 28223
Drew.Polly@uncc.edu

Received: 3 December 2014 Revised: 18 March 2015 **DOI: 10.1564/tme_v23.1.01**

This study examined the influence of professional development on elementary school teachers' perceptions of and use of an internet-based formative assessment tool focused on students' number sense skills. Data sources include teacher-participants' pre and post survey, open ended response on post survey, use of the assessment tool and their written responses completed during online professional development modules. Through an inductive analysis of teachers' written reflections and open ended survey response, participants reported that the use of the formative assessment tool supported their instruction, provided opportunities for teacher collaboration, and served as a vehicle for teachers' own professional learning. A quantitative analysis of the pre and post survey indicated a statistically significant increase in teacher practices to be more student centered. Implications for future research related to professional development focused on supporting teachers' internet-based tools are also shared.

Key words: formative assessment, number sense, primary grades, internet-based tool

1 FORMATIVE ASSESSMENT IN MATHEMATICS

Formative assessment has the potential to provide mathematics teachers with valuable information about their student's mathematical understanding (Joyner & Muri, 2011; Koellner, Colsman, & Risley, 2009; Wiliam, 2007). Researchers have found that when teachers integrate formative assessment practices into their daily instruction they have seen improvements in the frequency of developmentally-appropriate activities and slight gains in student achievement (Polly, Wang, Martin, Lambert, & Pugalee, accepted; Black & Wiliam, 1998; Wiliam, 2011).

Still, though, research studies have documented that teachers struggle to consistently collect and use formative assessment data related to their students' mathematical understanding (Polly et al., 2014; William, 2011). While trying to formatively assess students, teachers often stop teaching in order to assess, or focus on instruction and don't collect valuable assessment data (Martin & Polly, 2015). Abrams (2007) indicated teachers felt instructional time must be devoted to covering standards and that they were unable to devote time to formative assessment. Collecting adequate data and the time allotted to formatively assessing students are barriers as well as the lack of resources. Cizek (2010) stated the resources for summative assessment far exceed those for formative assessment. Teachers cited instructional time is limited and the time needed to create resources for formative assessment in their classroom is also limited. Digital technologies offer additional resources to address some of the concerns (Polly et al., 2014). *AMC Anywhere* is one example and is at the center of this study.

Technology's Role in Formative Assessment

Technologically-enhanced formative assessment tools, especially those that are internet-based, have potential to support teachers' efforts in collecting formative assessment tools. Past studies have found that the use of internet-based formative assessment tools, such as hand-held clickers, enables teachers to easily collect the data and allows teachers to focus their attention on analyzing the data and making instructional decisions based on the data (Polly, Little, & Rodgers, 2015). Another research study has found that teachers using an internet-based tool to individually assess students reported that the assessment process is cumbersome, but that the data analysis process was very easy due to the technology (Polly et al., accepted). Further, teachers reported that their use of technological tools for formative assessment was greatly influenced by their school culture and the amount of support that they received from their administration and colleagues in regards to conducting formative assessment and the types of preferred assessments (Lee, Feldman, & Beatty, 2011).

In literacy, internet-based formative assessments have been used for over a decade to assess students' reading and comprehension skills (Goodman, 2006). Research on literacy formative assessments found that teachers used the tool to collect data, but reported either difficulties or a lack of interest in using the data to inform their instructional decisions (Hoffman, Jenkins, & Dunlap, 2009).

Assessing Mathematics Concepts: *AMC Anywhere*.

Assessing Mathematics Concepts Anywhere (*AMC Anywhere*) is an internet-based formative assessment system that was designed by Kathy Richardson and her research work on the critical learning phases of number sense (Richardson, 2012). The assessments focus on concepts of counting, comparing quantities, composing and decomposing numbers, place value, and addition and subtraction. *AMC*

Anywhere provides teachers with a technology-enhanced way to examine progress and student needs by generating reports that summarize student results. Reports at the student level, class level, grade level, school level, and district level are accessible from the system. *AMC Anywhere* assessments produce reports for individual students with the scoring A, P+, P, P-, I, and N. The letters represent Apply, Practice, Instruction, and Needs prior skill.

During the professional development the project focused on the formative assessments about counting skills (Counting Objects and Number Arrangements), and skills related to parts of a number (Hiding Assessment). The assessment provides teachers with the opportunity to assess students individually and based on the information entered into a computer or iPad, the size of the numbers that students are working with will change until the assessment ends. The assessments are linked to Richardson's instructional materials, *Developing Number Concepts* (Richardson, 1998), as well as the Common Core State Standards (CCSSI, 2010).

Theoretical Framework: Learner-centered Professional Development (LCPD)

This study is grounded in the theoretical framework of learner-centered professional development ([LCPD]; National Partnership for Educational Accountability in Teaching, 2000; Polly & Hannafin, 2010;). LCPD is grounded in the American Psychological Association's *Learner-centered Principles* (Alexander & Murphy, 1998; APA Work Group, 1997) and aligns to contemporary research on teacher professional development (Polly & Hannafin, 2010; Polly, 2011). Through a synthesis of empirical studies on teacher professional development and the *Principles*, components of LCPD were identified. They include: opportunities for teachers to address student learning needs (Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2009; Yoon, Kwak, Duncan, Lee, Scarloss, & Shapley, 2007), actively engage teachers in developing both knowledge of content and pedagogy (Garet et al., 2001; Penuel, Fishman, Yamaguchi, & Gallagher, 2007), provide teachers with ownership and choice about their professional learning activities (NPEAT, 2000), support teachers' collaboration with colleagues and more knowledgeable others (Borko, 2004; Hawley & Valli, 2000), provide ongoing support over a sustained amount of time (Polly & Hannafin, 2011; Loucks-Horsley et al., 2009), and develop teachers' use of knowledge and skills through classroom-embedded learning experiences and reflections about those activities (Borko, 2004; Hawley & Valli, 2000).

2 RESEARCH QUESTIONS

This study examines teacher's perspectives during their participation in a year-long professional development programme designed to support their use of a technology-enhanced formative assessment programme that focuses on primary students' understanding of number sense. This study is grounded in the following research questions:

1) How does professional development influence teachers' use of the *AMC Anywhere* instructional tool and mathematics instructional practices?
2) What are elementary school teachers' perspectives related to using a formative assessment tool to examine their students' number sense skills?

3 METHODS

Context: Assessment Practices to Support Mathematics Learning & Understanding for Students (APLUS)

Assessment Practices to Support Mathematics Learning and Understanding for Students *(APLUS)* is a funded Mathematics and Science Partnership (MSP) project that was created for the purpose of assisting teachers in developing the skills needed to formatively assess students number sense and understanding and to use the data to inform their instruction. APLUS included six school districts across a large state in the southeastern United States. During the year which we are examining in this paper, there were 148 teacher-participants. Professional development (PD) was provided to teachers in the summer for five days (8 hours per day). After the summer PD, follow-up PD (40 hours) was in the form of three on-line modules Teacher participants completed a survey about their teaching practices. Teaching practices were measured with 25 items on a 5-point Likert scale with higher scores on teaching practices suggesting more teacher-centered approach. (see Appendix A for the survey). The teaching practices pre and post survey were administered at the beginning of the summer PD and at the last day of the summer PD. Thirteen items (Items 1, 2, 3, 4, 8, 9, 10, 13, 14, 18, 19, 22, and 23) were indicators of teacher-centered practices whereas 12 (Items 5, 6, 7, 11, 12, 15, 16, 17, 20, 21, 24, and 25) were indicators of student-centered practices. The 13 items related to student-centered practices were reversely coded so that participants whose scores were higher were more teacher-centered than scores that were lower and more student-centered.

The teacher participants engaged in three on-line modules (approximately 8 hours of work each) that extended the summer workshop content. These modules also included participants' use of the AMC Anywhere system and analyzing their data to inform instructional decisions. Module 1 focused on prior experience with formative assessment and establishing a classroom culture of assessing students' mathematical understanding. Module 2 emphasized using AMC Anywhere to examine data and implement data-based instruction, while Module 3 emphasized using Number Talks as a way to discuss and reason about mathematics and use that as a vehicle to assess students' understanding. Participation in each module required teachers to respond to posts from their fellow colleagues.

4 DATA SOURCES AND DATA ANALYSIS

Data sources include the pre and post teacher practices survey, the open ended responses to the post survey question on future classroom evaluation and teachers' postings on the online discussion forum that was part of the professional development projects. A statistical analysis of the pre and post survey and a qualitative examination of the

open ended responses were analyzed using thematic analysis (Coffey & Atkinson, 1996). The researchers organized the open ended response analysis into categories by themes (Ezzy, 2002). The quantitaive and qualitative analyses of these data pieces addressed our first research question. The second research question focused on the on-line module professional development. Teacher-participants posted three times during the year in response to various modules on formative assessment, their use of AMC Anywhere to analyze their students, and the use of Number Talks as a vehicle to formatively assess their students' mathematical thinking. Data was examined by the members of the research team and organized according to topics that were determined apriori, based on the focus of the project. These topics were experiences with formative assessment, the AMC Anywhere tool, Number Talks, and general challenges. Once data excerpts were read summaries were written for each of the categories and salient data pieces were selected that best illustrate teachers' perspectives. The data were then rechecked to make sure that they are accurately represented in each categorical description and quoted excerpt.

5 FINDINGS

Research Question #1 How does *AMC Anywhere* professional development influence teachers' use of the *AMC Anywhere* instructional tool and mathematics instructional practices?

The Teacher Practices Questionnaire (Swan, 2004) was administered to teachers as the first activity on the first day and as the last activity at the end of the final day. The teacher practice post survey included an open response question that allowed teachers to reflect on the professional development and share their plans for their future practices. The most common themes are described below.

The workshop and *AMC Anywhere* facilitates assessment of individual students. One of the most common themes on the questionnaire focused on the idea that the professional development and the use of the internet-based *AMC Anywhere* system facilitated teachers' assessment of individual students, especially student misconceptions or errors related to number sense. There were 222 open ended teacher responses on the post survey and 33% indicated the assessment offered insight into students' individual understanding. The workshops focused heavily on the "illusion of learning," which includes times where students can follow a procedure or mathematical algorithm, but do not really understand the concept. At the end of the project, teachers reported positive beliefs that *AMC Anywhere* can support their assessment of student's understanding.

One teacher remarked:

> "I feel like using the online assessments that we were trained in has helped me to be more specific and precise with data being collected, which helps me gear instruction to wherever the children are at with each skill. Because the assessments each focus in on such specific concepts, it makes it easy to see where children need extra support, where they are solid, and where they need to go next. I love how easy it is to collect and interpret data through this approach."

Another participant noted, "Wow! It is amazing to see what the students actually know and where the breakdown begins." Through the process of conducting the *AMC Anywhere* assessments and analyzing the data teachers were able to pinpoint individual students' understanding and mathematical abilities.

AMC Anywhere supports differentiated mathematics instruction. Another common theme found in 43% of the post survey open ended responses was the support the AMC data and learning materials provided for differentiated instruction. Throughout the professional development activities, teachers analyzed mathematical data, implemented activities in their classroom, and reflected on their experiences with students. Each of these activities supported and provided a venue for differentiated instruction, in which teachers would look at the *AMC Anywhere* data, the associated *Developing Mathematics Concepts* (DMC) materials or other materials, and implement differentiated activities that were based on data about students' mathematics ability.

On the post-project survey a teacher reported:

> "I saw the importance of cross-class intervention. I also saw that it was easy to use these activities to allow students to work on the same game, but at individual levels. You can collect data quickly with this and group students by individual abilities."

At the end of the summer workshops before the school year, a teacher commented, "Our math block will become much more differentiated and will allow students to become independent learners and confident in solving/ making sense of mathematics problems."

The workshop influenced my use of questioning strategies. Several teachers indicated that the professional development helped them to realize that their questioning strategies needed to be deeper and broader for each activity. These responses were nested in the 43% of responses regarding differentiated instruction. One teacher noted: "I will use questioning to collect data about more than one goal using the same activity but different directions."

Another teacher noted the need to focus questions more on mathematics concepts rather than answers. She wrote, "I have changed my questioning strategies to focus on the concepts students need to develop number concepts."

Increase in use of student-centered pedagogies. The pre/post survey specifically examined whether the professional development experiences influenced teachers' enactment of student-centered pedagogies. The project emphasized the use of differentiated instruction, deeper questioning, grouping students with students' of similar ability, and to allow the needs of the individual learner rather than the order of units in a particular curriculum drive instruction align with that of a student centered teacher.

Descriptive statistics about teacher practices for pre and post survey data are presented in Table 2.

	Pre (n = 126)	Post (n = 148)
Participants	3.19 (0.33)	2.95 (0.45)

Table 2 Teacher Practices Survey Results

Independent samples *t*-tests indicates that teacher participants tended to be more student-centered in practice after the PD, $t(116) = 5.54$, $p < .001$. The survey indicates that the week-long summer professional development workshops had an impact on teacher practices. The post survey emphasizes a movement to student centered teaching and this is well supported in the open-ended post survey responses.

Research Question #2: What are elementary school teachers' perspectives related to using a formative assessment tool to examine their students' number sense skills?

The on-line module data analysis offers insight into teachers' perspectives related to using this formative assessment tool. Teacher perspectives on formative assessment, the AMC tool, and challenges faced are presented to address our second research question.

Teacher perspectives on formative assessment. The teachers' responses indicated they were using data and assessments before they became part of the grant. The responses included below show a range of the types of formative and summative assessments teachers reported as part of the data used in their instruction. The responses show variation between the teachers.

> *It seems I have heard the admonition of "data driven instruction" for years! The source of that data changes over time and with the district and its schools: district formatives came and went; common assessments using ThinkGate (no longer); common assessments analyzed in house depending on the availability of someone proficient in crafting spreadsheets; AIMS Web here and there; MAPs; and now AMC/KR, and also DreamBox. Our school's upper elementary teachers are also fond of Accelerated Math, which we funded again this school year.*

This first response indicates an emphasis on assessment data and the use of many sources to gather both summative and formative data. The teacher shows some level of exasperation with the amount of programmes introduced and their lack of longevity. This sentiment was echoed in many teacher posts.

> *The evidence I use is conferencing /notes, small group work, and assessments. I use evidence from math talks.*
>
> *Prior to this year, the data we had was mostly anecdotal observations, common grade-level assessments, and an occasional district/state assessment.*
>
> *The data that we used prior to this year was very general. We used formal assessments to inform parents and in grading. We have limited data to share at IEPs and with RTI teams.*

The next few responses show the use of assessment as a more informal classroom based process. The large scale assessment initiatives appear to be minimal for these teachers. The last two responses seem to express the notion that their prior assessment practices may not have been adequate for gathering information on student learning.

The first teacher highlights data driven instruction as being a focus of the district and school; however, it continues to change and be affected by the faculty available to support the organization of the data. The other responses show teachers using their own classroom notes and anecdotes to plan for instruction and there seems to be a sentiment that this was limited. Although a variation in the prior use of data is evident, most responses did exhibit that teachers recognized the value of assessment.

> *I have been teaching for many years and have seen data change a lot through the years. This helps for grouping children so that they are working at their level. It shows areas in which the child is struggling. It is a great tool to help explain students' progress or delays to parents or for RTI paperwork.*

Teachers emphasized assessment data as an important piece in developing groups, informing parents, and creating interventions. The AMC programme and Kathy Richardson support materials became part of the assessment landscape for the teachers in the grant.

Teacher perspectives on the *AMC Anywhere* tool. Developer Kathy Richardson identifies the "Critical Learning Phases" that are part of the AMC nine assessments which are designed to be formative, summative, and diagnostic, to pinpoint what a child knows and still needs to learn**,** these short interview assessments are a cohesive look at the development of students' understanding of core math concepts (Math Perspectives, 2013). The responses indicated the teachers felt this programme was beneficial for instruction, collaboration, and their own personal growth. Below are a few representative quotes from the participants.

> *Now we have data to use. We can break it down by individual skills. We use that data to form small skill based learning groups. We can show parents specific areas that need improvement. It helps us to communicate better with EC teachers, parents, students, coaches, and administration. We can see the progress. If no progress is happening then we change our intervention.*

In this response the teacher focuses on what the data shows about the learner, how this information informs the intervention, enhances communication with all parties, and progress monitoring. AMC allows this teacher to understand

the individual student and make plans to encourage progress. The next posts also noted these benefits.

> *I feel like using the online assessments that we were trained in has helped me to be more specific and precise with data being collected, which helps me gear instruction to wherever the children are at with each skill. Because the assessments each focus in on such specific concepts, it makes it easy to see where children need extra support, where they are solid, and where they need to go next. I love how easy it is to collect and interpret data through this approach.*
> *I am much better at using data this year than last. I do use it to plan for how I should start each math lesson, as well as planning for who to pull for small groups-extra practice with me or the teacher assistant and how to pair up the partners. I am using the data to drive how I plan the lessons, remediate and enrich.*

These posts indicate the teachers found AMC easy to use, the data produced to be concept specific, and the reports were accessible for interpretation. These posts, as with the first one, show data driven instruction; however, they focus on "small group" and "children" as opposed to the more individualized focus in the first post. The next responses present the benefits of the assessment tool for collaboration.

> *We have a greater source of strategies that we can use to drive our instruction. We are also using the data to determine if one or more teachers on our grade level is having more success with any given topic or concept. We, in turn, collaborate with each other to share strategies to enhance the success of all students.*
> *I analyze data for trends within a grade level and across CCSS strands to determine areas of strength that another teacher may wish to observe and discuss, and areas that need strengthening and how to best provide that support.*

These posts show how the AMC data is used to identify teachers that are having success with a topic to encourage sharing of strategies and areas that a teacher may need support. The responses appear to value the additional avenues for collaboration provided by AMC. There were no responses that indicated the data was used in any way to penalize teachers. These responses suggest the teachers benefited from having the technology needed to assess students at the individual level, move them on to higher or lower assessments, generate a report per the individual or class, and found this data to be easier to share and use in instruction. The specificity of the assessments, the ability to assess at any time, ease of collection and interpretation all appear to be positives for the teachers.

Teacher perspectives of challenges. The opportunity to discuss challenges was included in several areas of the professional development. The majority of the teachers noted time constraints explicitly, while others indicated struggling to balance all the instructional practices that they felt were beneficial for these students. The balance challenge may be also attributed to the time constraint.

> *It has been difficult to balance the amount of whole group instruction, small group instruction, and independent activities to meet the developmental needs of my students, while still meeting the math objectives for my grade level.*
> *This feels like a rushed amount of time in which to practice previously learned skills as well as introduce new concepts.*
> *My challenges so far are trying to teach common core/pacing and incorporating Kathy Math too. It is also a challenge to teach all objectives in an hour. (This is the time allowed for my day).*
> *Finding time, keeping track of materials, keeping on track/top of what groups kids are in, being ready to move them as soon as they are ready.*

These first four posts reveal the challenge teachers feel with trying to meet objectives, balancing different types of instruction, and recognizing the individual student needs. There is a sense that the teachers value each of these components and want to be successful in each area. The next posts also indicate a constraint on time; however, the teachers present more specific instructional pieces that are affected versus the broad picture presented above.

> *One of my greatest challenges is finding time beside the morning clubs to have them work on the activities My biggest challenge is time!!! I've tried to gather materials for some games/activities, then I think oh I need to do this and that and I lose track of what I'm doing. I think I try to do too much at one time.*
> *The AMC materials are awesome but having enough time to play the games is a sometimes a challenge.*

These three responses highlight games and activities as the instructional practices that seem to be neglected due to time limitations. The teachers' responses seem to show they value these practices and would like to have more instructional time to allow students to engage in games and activities.

The teachers' comments also mentioned time constraints related to conducting the assessments in the context of also having to teach lessons and also assess their students' literacy instruction. Their responses suggest they feel the instructional materials and assessments are beneficial for their mathematics instruction when they are able to establish a classroom structure. Overall, teachers expressed the desire to have more time to plan and teach mathematics in order to plan for and implement small group instruction, games, activities, and to regularly assess their students.

6 DISCUSSION AND IMPLICATIONS

This study examined the perspectives and enacted pedagogies of teachers engaged in a yearlong professional development (PD) programme focused on using the internet-based formative assessment tool *AMC Anywhere*. The

findings of the study indicated that the PD led teachers' instruction to become more student-centered, that teachers found the internet-based tool to be helpful for formative assessments, and that teachers used the tool to make data-based instructional decisions. However, teachers also reported challenges in implementation. In this section we detail the findings in more depth.

Influence of Learner-centered Professional Development on Formative Assessment

The Learner-centered Professional Development (LCPD) construct employed in this study indicated a positive influence on teachers' instructional practices. The professional development actively engaged teachers with actual students, video analysis, collaboration with other teachers, support from PD leaders, and the PD continued throughout the year (Loucks-Horsley et al., 2009). During the workshops and the online modules, teachers used the the internet-based formative assessment tool with actual students and reported how it changed their perception of students' mathematical understanding, especially in light of the "illusion of mathematical learning" concept that was frequently discussed during the PD. Coupled with the use of the *AMC Anywhere* tool to collect data, teacher-participants used the tool to analyze data and make instructional decisions using related instructional materials.

The weeklong immersion in the type of activities embodied by LCPD programmes prompted teachers to focus on student-centered pedagogical strategies with a focus on how they can best support their students' learning (Hawley & Valli, 1999; Polly & Hannafin, 2010). To this end, many teachers in their survey responses indicated a focus on differentiation, individualized instruction, and student centered questions, and using student data to drive instruction. The continuation of PD using three on-line modules created a space for teachers to become a community and share their individual experiences within their district and school. It was within these posts that teachers shared their perspectives on formative assessment, technology, and the challenges they face.

Use of Technology for Formative Assessment

The *AMC Anywhere* tool offers teachers a way to work with individual students on formative assessments that indicate the student's mathematical understanding and what level of support the student needs to progress (Polly et al., accepted). This technology synthesized the data gathered from the assessments and allowed teachers to generate reports on the individual student and the whole class. The teachers indicated that the ease of generating these reports and the specificity of the data were directly impacting their instruction. The teachers noted that the reports were used in collaboration with other teachers on their team. The data was shared with parents with suggestions to work on particular mathematics concepts at home. Polly et al., (2014) found teachers felt that the data analysis process was greatly enhanced due to technology. Further, the findings from this study showed *AMC Anywhere* provided data analysis and reports that were accessible for all stakeholders and easy to produce. Lee, Feldman, and Beatty (2011) reported the use of technology tools for formative assessment was influenced by the school culture and administrative support. Fullan (2002) suggests that principals need to be instructional leaders in order to be effective in large-scale education reform. Some of the challenges found in this study are connected to these areas.

Addressing Challenges

Teachers expressed their perspectives on formative assessment and the challenges they face in implementation. The teacher participants showed a strong belief in the positive effects and need for formative assessment. There seem to be a large number of teachers that were inundated with various tools for collecting both summative and formative assessment data. The responses indicated that these tools and support materials were changing often and causing frustration with the lack of focus and available support. There were also a large number of teachers that noted their formative assessment practices were informal and that large scale formative assessment initiatives were not part of their school culture. In both cases, the teachers lacked a consistent well supported way to collect accurate formative data that could be used in collaboration with other teachers, parents, and to assist in planning individualized instruction. The APLUS grant involves six districts around North Carolina and all districts are working towards building capacity to continue to use *AMC Anywhere* well beyond the duration of the grant. This will increase the likelihood for district leaders to support teachers in addressing some of the inconsistencies shared in their online responses. Future research should examine the ways in which school leadership and culture can support educational reform (Fullan, 2002; Lee, Feldman, & Beatty, 2011).

Another challenge that was consistently shared by teachers was the time constraint they feel when trying to balance teaching the Common Core Standards, implement varying types of instruction, identify individual needs, and plan accordingly. This may also be connected with teachers' tendency to use the data to create learning groups rather than more individualized instruction. The challenge of time is expressed by teachers across subject areas (Brand & Triplett, 2012). The teacher responses and influence of professional development found in this study indicate a few ways to address these challenges. First, as indicated by teacher responses, schools should commit to a manageable amount of resources to be implemented per subject area and work to create leaders to support faculty. Second, continued professional development is essential for teachers to learn and implement tools in ways that focus on individual learners and for the implementation to become time efficient (Polly & Hannafin, 2011; Heck et al., 2008).

Implications for Further Research

The findings from this study indicate that the professional development positively influenced teachers' preparation of and use of the internet-based formative assessment mathematics tool *AMC Anywhere*. Further, and perhaps more importantly, teachers reported a shift towards

using more student-centered pedagogies in their classrooms while teaching mathematics. In light of these findings, future research studies should drill down deeper to collect more intensive data about the specific process that teachers go through to use the tool, analyze the data, and make instructional decisions (Martin & Polly, 2015). This work can be done through a combination of surveys, interviews, and observations of teachers.

Further, *AMC Anywhere* includes assessments that align to the Common Core Standards in Grades Kindergarten through Grade 2. To that end, further research should consider the variance across grade levels to see if teachers in different grade levels are using the formative assessment tool and its data differently from other grade levels. Lastly, the follow-up online professional development modules created a professional learning community (Dufour, Dufour, & Eaker, 1998) of sorts with a mechanism for support and collaboration. Research examining the longevity, teacher participation, and fidelity to the growth of *AMC Anywhere* should continue in order to identify ways in which to make large scale professional development more effective.

Note: This study is supported by a North Carolina Mathematics Science Partnership grant funded by the U.S. Department of Education. This paper does not reflect the view and opinions of the (state) or the United States Department of Education.

REFERENCES

Abrams, L.M. (2007). Implications of high-stakes testing for the use of formative classroom assessment. In H. McMillan (Ed.), *Formative assessment classroom: Theory into practice* (pp. 70-98). NY: Teachers College Press.

Alexander, P. A. & Murphy, P. K. (1998). The research base for APA's learner-centered psychological principles. In N. M. Lambert & B. L. McCombs (Eds.), *Issues in school reform: A sampler of psychological perspectives on learner-centered schools* (pp. 33-60). Washington, DC: American Psychological Association.

APA Work Group of the Board of Educational Affairs (1997). *Learner-centered psychological principles: A framework for school reform and redesign*. Washington, DC: Author.

Black, P. & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education, 5*, 7-71.

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher, **33*(8)**, 3-15.

Brand, B. R., & Triplett, C. F. (2012). Interdisciplinary Curriculum: An abandoned concept?. *Teachers and Teaching: Theory And Practice*, *18*(3), 381-393.
Cizek, G. J. (2010). An introduction to formative assessment: History, characteristics, and challenges. In H. Andrade & G. Cizek, (eds.) *Handbook of formative assessment* (pp. 3-17). New York: Taylor and Francis.

Coffey, A., & Atkinson, P. (1996). *Making sense of qualitative data: Complementary research strategies*. Sage Publications, Inc.

Common Core State Standards Initiative (2010). *Common Core State Standards- Mathematics*. Retrieved from: http://corestandards.org.

Ezzy, D. (2002). *Qualitative analysis: Practice and innovation*. London: Routledge.

Fullan, M. (2002). The change. *Educational leadership*, ***59*(8)**, 16-20.

Goodman, K. S. (2006a). A critical review of DIBELS. In K. S. Goodman (Ed.), *The truth about DIBELS: What it is, what it does* (pp. 1–39). Portsmouth, NH: Heinemann.

Hawley, W. D. & Valli, L. (2000). Learner-centered professional development. *Research Bulletin*, August 2000, No. 27. Phi Delta Kappa Center for Evaluation, Development, and Research. Retrieved February 22, 2005, from http://www.pdkintl.org/edres/resbul27.htm

Hoffman, A. R., Jenkins, J. E., & Dunlap, S. K. (2009). Using DIBELS: A survey of purposes and practices. *Reading Psychology*, *30*, 1-16.

Joyner, J. & M. Muri. (2011). *Informative assessment: Formative assessment to improve math achievement Grades K-6*. Sausalito, CA: Math Solutions.

Koellner, K., Colsman, M., & Risley, R. (2011). Multidimensional Assessment. *Teaching Exceptional Children*, ***44*(2)**, 48-56.

Lee, H., Feldman, A., & Beatty, I. D. (2011). Factors that affect science and mathematics teachers' initial implementation of technology-enhanced formative assessment using a classroom response system. *Journal of Science Education and Technology*, *21*(5), 523-539.

Loucks-Horsley, S., Stiles, K. E., Mundry, S., Love, N., & Hewson,P. W. (2009). *Designing professional development for teachers of science and mathematics* (3rd ed.). Thousand Oaks, CA: Corwin Press.

Martin, C.S. & Polly, D. (2015). Using the AMC Anywhere web-based assessment system to examine primary students' understanding of number sense. In D. Polly (Ed.), *Cases on Technology Integration in Mathematics Education* (pp. 366-377). Hershey: PA: IGI Global. DOI: 10.4018/978-1-4666-6497-5.ch018.

National Partnership for Excellence and Accountability in Teaching (NPEAT) (2000). *Revisioning professional development: What learner-centered professional development looks like*. Oxford, OH: Author. Retrieved September 10, 2003, from http://www.nsdc.org/library/policy/npeat213.pdf

Penuel, W. Fishman, B., Yamaguchi, R., & Gallagher, L. P. (2007). What makes professional development effective? Strategies that foster curriculum implementation. *American Educational Research Journal, 44*, 921-958.

Polly, D. (2011). Developing teachers' technological, pedagogical, and content knowledge (TPACK) through

mathematics professional development**.** *International Journal for Technology in Mathematics Education*, ***18*****(2)**, 83-96.

Polly, D. & Hannafin, M. J. (2011). Examining how learner-centered professional development influences teachers' espoused and enacted practices. *Journal of Educational Research, 104*, 120-130.

Polly, D., Little, M., & Rodgers, E. (2015). Leveraging interactive clickers as a tool for formative assessment in elementary school mathematics. In D. Polly (Ed.), *Cases on Technology Integration in Mathematics Education* (pp. 331-350). Hershey: PA: IGI Global. DOI: 10.4018/978-1-4666-6497-5.ch016.

Polly, D., Wang, C. Martin, C.S., Lambert, R.G., Pugalee, D.K., Stephan, M., & Ringer, C. (2014, April). Examining the influence of professional development on primary students' mathematical achievement. Paper presented at the 2014 Annual Meeting of the American Educational Research Association. Philadelphia, PA.Richardson, K. (2012). *How Children Learn Number Concepts: A Guide to the Critical Learning Phases.* Bellingham, WA: Math Perspectives.

Richardson, K. (1998). *Developing Number Concepts: Counting, Comparing, and Pattern*. New York: Dale Seymour.

Swan, M. (2004). Designing and using research instruments to describe the beliefs and practices of mathematics teachers. *Research in Education, 75*, 58-70

Wiliam, D. (2007). Five "Key Strategies" for Formative Assessment: NCTM Research Brief. Retrievedfrom:http://www.nctm.org/uploadedFiles/Research_News_and_Advocacy/Research/Clips_and_Briefs/Research_brief_04_-_Five_Key%20Strategies.pdf

Wiliam, D. (2011). What is assessment for learning? *Studies in Educational Evaluation*, ***37*****(1)**, 3-14.

Yoon, Kwak S.; Duncan, Teresa; Lee, Silvia W.-Y.; Scarloss, Beth; & Shapley, Kathy (2007). *Reviewing the evidence on how teacher professional development affects student achievement* (Issues & Answers Report, REL 2007–No. 033). Washington, DC: U.S. Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance, Regional Educational Laboratory Southwest. Retrieved December 31, 2008, from: http://ies.ed.gov/ncee/edlabs

BIOGRAPHICAL NOTES

Christie Martin is an assistant professor in the Department of Teaching and Instruction at the University of South Carolina in Columbia, SC. Her research interests focus on examining writing across the curriculum and supporting teachers' use of effective instructional practices.

Drew Polly is an associate professor in the Department of Reading and Elementary Education at the University of North Carolina at Charlotte. His research interests focus on examining how to best support teachers' enactment of learner-centered instructional practices.

Chuang Wang is a professor in the Department of Educational Leadership at the University of North Carolina at Charlotte. His research interest include evaluating and assessing the impact of professional development on teachers' practices and student achievement.

Richard G. Lambert is a professor in the Department of Educational Leadership and the Director of the Center for Educational Measurement and Evaluation (CEME) at the University of North Carolina at Charlotte. His research interests include program evaluation of large initiatives as well as examining factors related to teacher stress.

David K. Pugalee is professor of education and Director of the Center for STEM Education at University of North Carolina at Charlotte. He received his PhD from the University of North Carolina at Chapel Hill. He has also taught middle grade mathematics and science. He has authored numerous books, book chapters, and articles on effective STEM teaching and learning.

APPENDIX A
Post -Teacher Practices Questionnaire

Name: _____Grade_____ Ethnicity_____

Years of experience in current grade level: _____ Gender _____ District ID _____ Indicate the frequency with which you think you utilize each of the following practices in your teaching by **circling** the number that corresponds with your response.

	Practice	Almost Never	Sometimes	Half the time	Most of the time	Almost Always
1.	Students learn through doing exercises.	1	2	3	4	5
2.	Students work on their own, consulting a neighbor from time to time.	1	2	3	4	5
3.	Students use only the methods I teach them.	1	2	3	4	5
4.	Students start with easy questions and work up to harder questions.	1	2	3	4	5
5.	Students choose which questions they tackle.	1	2	3	4	5
6.	I encourage students to work more slowly.	1	2	3	4	5
7.	Students compare different methods for doing questions.	1	2	3	4	5
8.	I teach each topic from the beginning, assuming they don't have any prior knowledge of the topic.	1	2	3	4	5
9.	I teach the whole class at once.	1	2	3	4	5
10.	I try to cover everything in a topic.	1	2	3	4	5
11.	I draw links between topics and move back and forth between topics.	1	2	3	4	5
12.	I am surprised by the ideas that come up in a lesson.	1	2	3	4	5
13.	I avoid students making mistakes by explaining things carefully first.	1	2	3	4	5
14.	I tend to follow the textbook or worksheets closely.	1	2	3	4	5
15.	Students learn through discussing their ideas.	1	2	3	4	5
16.	Students work collaboratively in pairs or small groups.	1	2	3	4	5
17.	Students invent their own methods.	1	2	3	4	5
18.	I tell students which questions to tackle.	1	2	3	4	5
19.	I only go through one method for doing each question.	1	2	3	4	5
20.	I find out which parts students already understand and don't teach those parts.	1	2	3	4	5
21.	I teach each student differently according to individual needs.	1	2	3	4	5
22.	I tend to teach each topic separately.	1	2	3	4	5
23.	I know exactly which topics each lesson will contain.	1	2	3	4	5
24.	I encourage students to make and discuss mistakes.	1	2	3	4	5
25.	I jump between topics as the need arises.	1	2	3	4	5

This questionnaire was adapted from Swan, M. (2004). Designing and using research instruments to describe the beliefs and practices of mathematics teachers. *Research in Education, 75*, 58-70. Permit for use was obtained on May 29, 2009

	Goals	Poor	Fair	Good	Very Well	Excellent
1.	How well can you collect student data?					
2.	How well can you analyze student data?					
3.	How well can you interpret student data?					
4	How well can you plan instruction based on student data?					
5.	How well can you differentiate instruction based on student data?					

1) How did the professional development influence how you plan on **collecting** and **using** data this year?