Designing Mathematics Instruction Utilizing *Crowdsourcing* as a Professional Development Model

Catherine Scott
The University of North Carolina at Chapel Hill

Designing Mathematics Instruction Utilizing Crowdsourcing is based on the logical assumption that if a group of teachers collaborate to continuously improve the alignment between the Common Core State Standards (the intended curriculum), what and how the content is taught (the enacted curriculum), how students are assessed (the assessed curriculum), and what students learn (the learned curriculum), then instructional practice will improve and student achievement in mathematics will increase. This professional development model is a pilot study intended to measure the potential effects of using crowdsourcing with high school mathematics teachers to develop, implement, and assess the curriculum being taught.

INTRODUCTION

Teachers are barraged by new information on high-stakes testing, hands-on teaching, inquiry models of instruction, technology infusion, common core standards and its associated benchmarks, social networking and other identified reform-minded practices. Implementing professional development (PD) with fidelity for early career teachers has become a huge challenge in many of these areas. This pilot study was an attempt to encourage teachers to focus deeply on their subject area in particular, recognizing that pedagogical practices stem from that center. In particular, this project sought to enhance professional development around Probability by inviting math teachers to design classroom materials using a method called *Crowdsourcing* to obtain feedback and suggestions from a broader range of math teachers, who implemented and critiqued lessons. According to Merriam-Webster's' dictionary (2014), *Crowdsourcing* is the practice of obtaining needed services, ideas, or content by soliciting contributions from a large group of people, and especially from an online community. *Crowdsourcing* combines the efforts of crowds of self-identified volunteers, where each one, on their own initiative, adds a small portion that combines to create a greater result. The idea described in this manuscript brought crowdsourcing into the realm of teacher professional development.

Crowdsourcing is a method of PD that has many similarities to the Engineering Design Process used by teams of engineers to plan, design, and develop new products and materials. They ensure healthy ecosystems, explore energy production, design, manufacture, and test essentially every product in modern society. Similarly, teachers plan, design, and develop instruction for a broad range of students with different needs (i.e. honors, English Language Learners, students with learning differences) in different contexts. Table 1 shows a comparison between the Engineering Design Process and the proposed method of *Crowdsourcing* to design instruction.

TABLE 1
DESIGN PROCESS COMPARISON: ENGINEERING VS. TEACHING

Engineering Design Process[1]	Instructional Design Process for Teacher PD
Steps of the Design Process 1. Identify the problem 2. Conduct Research. Identify criteria and constraints 3. Brainstorm possible solutions. 4. Select a design 5. Build a model or prototype 6. Test the model and evaluate 7. Refine the design 8. Share the solution	Steps of the Design Process 1. Identify the content area of focus for the professional development. 2. Identify the Common Core Standards that must be met 3. Brainstorm possible instructional strategies 4. Select a design 5. Create materials 6. Field test materials in classrooms 7. Refine materials 8. Share the materials with the mathematics education community

Note: [1] Engineering Design process located at http://www.sciencebuddies.org/engineering-design-process/engineering-design-compare-scientific-method.shtml

The PD model in this study focused on using crowdsourcing within the instructional design process with high school mathematics teachers to create a unit of instruction on probability.

RESEARCH BASED PROFESSIONAL DEVELOPMENT

The professional development activities described in this study align with research identified attributes of effective PD including: 1) a focus on teachers' identified needs (Hill, 2009); 2) opportunities for teachers to be active participants in the planning and execution of the professional development (Clark & Florio-Ruane, 2001); 3) encourages collaboration and brings teachers together in productive learning communities (Swenson, 2003; Lieberman, 1995; Grossman, Wineberg & Woolworth, 2001); 4) centers on teacher change and student learning (Borko, 2004, p.6); and 5) provides support during classroom implementation of the professional development (Ferguson, 2006).

Robinson and Carrington (2002) and Klinger (2004), found that professional development is "most effective when it is an ongoing process, which includes appropriate, well-thought-out training and individual follow-up" (Robinson & Carrington, 2002, p. 240). One way to avoid the oft-criticized one-size-fits-all quality of the PD is to cater it to teachers' individual needs and to offer specific feedback to teachers about their contextualized practice. Klinger (2004) found that "teachers have different internal characteristics and work in diverse contexts with varying external pressures, and it is important to consider these complex factors when planning for and conducting professional development programs" (p. 252) suggesting that professional development be differentiated to meet the needs of teachers just as teaching is differentiated for students.

One additional critical element of effective professional development is a focus on a particular content area. While much of the professional development offered to teachers emphasizes pedagogical approaches, few examples reveal a focus on supporting growth in teachers' content knowledge. Recent research in mathematics in particular emphasizes the need for content-centered professional development: "U.S. teachers need improved mathematics knowledge for teaching" (Ball & Hill, 2009, p. 330). Hill (2009) emphasizes the connection between teachers' own mathematical content knowledge and student achievement (p. 475) and asserts that, "…content-focused professional development based on classroom practice – including evidence around student learning, the study of curriculum materials, and so forth- is most likely to affect teacher knowledge and performance, and student outcomes" (Hill 2009, p. 474). Although most of the professional development research conducted by Hill and colleagues focused on

Early Childhood Mathematics teaching and learning, it is reasonable to assume that the same content-focused professional development can also be effective with Secondary Mathematics teachers. In an effort to implement research-based strategies for effective PD for mathematics teachers, we chose to design our professional development using a collaborative model based on teacher identified needs for classroom materials aligned to the high school Common Core State Standards (CCSS) for Mathematics (2010). The topic selected focused on Probability, with teachers at the center of the proposed design. Collegial support networks were used to help teachers implement professional development in their classrooms.

PARTICIPANTS AND SETTING

While the focus of schools of education has often been on teacher preparation, this study is focused more closely on the induction period. This model of professional development aligned with our commitment to support our graduates in their first through fifth year of teaching through a dialogic model of professional development. Early career teachers were the focus of this study because transition from a pre-service teacher to a beginning teacher is a difficult and delicate one. According to Ingersoll, Ingersoll, and Nieto (2003), it is during this crucial career stage, when new teachers are constructing their sense of professional self, that they are most vulnerable, particularly for leaving the profession. Turnover among the nation's teachers ranks significantly higher than for other professions, emphasized further by the alarming number of teachers leaving the profession during their first few years of teaching (Ingersoll, 2001; Ingersoll, 2003; Nieto, 2003). "Nearly half of all new teachers leave the field within the first five years" (Graziano, 2005).

Mathematics alumni in their first five years of teaching were invited via email to participate. The participants selected were early career mathematics teachers with 0-3 years of experience who expressed interest in working with other teachers to design a unit of instruction that could be implemented in their classrooms. Five high school mathematics teachers teaching diverse students in a variety of school settings (rural, urban, and suburban) participated in the pilot study and implemented one unit of instruction. Teachers who were selected to participate in the PD design team were responsible for sharing materials with professional learning communities (PLC) at their local schools. Participants teaching in different school districts enabled us to consider the needs of various school settings and gave us a broad perspective for designing materials that were field tested in rural, suburban and small city environments.

A DESCRIPTION OF THE PROFESSIONAL DEVELOPMENT ACTIVITIES

For the purpose of this project, *Crowdsourcing* is defined as a method of teacher PD that engages the participants during every phase of the PD experience, from design, to field-testing, revisions, and delivery. In this new form of PD, participants were actively engaged in the design process rather than passive recipients of information. Teachers collaborated with university faculty members to improve the alignment between the Common Core State Standards (the intended curriculum), what and how the content is taught (the enacted curriculum), how students are assessed (the assessed curriculum), and what students learn (the learned curriculum). This professional development project was a pilot study intended to measure the effects of a small group of teachers collaborating on a high school probability unit. The recipients of the professional development collaborated through an eight-step design process with step-one being completed prior to the professional development event and Probability being identified as the content area of focus. Steps for the design process included: 1) Selecting the content area of focus, 2) Identifying the Common Core Standards that must be met and researched the topic, 3) Brainstorming possible instructional strategies, 4) Selecting the design, 5) Creating and revising materials, 6) Field testing materials and strategies in classrooms, 7) Sharing ideas for revisions with colleagues then refining the materials, and 8) Sharing the materials with others in their professional learning communities. Table 2 contains a timeline with tasks and approximate dates these tasks were completed. Participants met face-to-face for three days to complete steps 3, 4 and 5 of the design process. Some of the dates were adjusted based on pacing guides for individual school districts where teachers were employed.

TABLE 2
PROFESSIONAL DEVELOPMENT TIMELINE

Date	Step of the Design Process	Description of activity
May:	**1:** Identify the content area of focus for the professional development.	University faculty members contacted participants by email and asked them to submit suggestions for areas of interest and need.
June-July:	**2:** Identify the Common Core Standards that must be met, research topic	Prior to the first face-to-face meeting, the university faculty prepared materials on the topic (probability) and had them available for participants. This included copies of Common Core Objectives; prerequisite content taught in grade K-8, research on best practices for teaching math, sample curriculum and assessments. Participants were asked to research the topic prior to the first meeting and bring ideas to share with the group.
July: Workshop Day 1	**3:** Brainstorm possible strategies	During Day 1 of the face-to-face portion of the PD, participants shared the materials they found on probability. University faculty members also shared materials and research-based strategies with participants and encouraged them to identify some good materials that could be used in the unit. They also identified missing components that would need to be developed.
July: Workshop Day 2	**4:** Select a design	Day 2 of face-to-face PD. Participants organized and selected only the materials that aligned to the standards (Appendix A). They designed assessments that aligned with content objectives and materials that needed to be developed or enhanced.
July: Workshop Day 3	**5** Create or revise materials	Day 3 of face-to-face PD. Participants took responsibility for developing the first draft of the unit of instruction then shared it with the group for revision. This portion was completed face-to-face then uploaded to an online sharing website for others to review.
October-December	**6** Field test materials/strategies in classrooms	University faculty updated materials and distributed draft #2. Participants shared materials with colleagues and taught the material to students in their classrooms, keeping notes on how students performed on assessments and how materials could be improved for the next implementation cycle. Participants uploaded implementation notes to a common online sharing site.
January	**7:** Share ideas for revisions, then redesign	After all participants had an opportunity to pilot materials with their students, they met online via video conference to discuss student performance, analyze feedback from the "crowd," and make revisions to the materials for greater distribution.
February	**8:** Share the materials with others	University faculty members consolidated teacher feedback and distributed draft #3 to the participants who were encouraged to disseminate material more broadly to mathematics educators in their school districts.

Some key findings that were noted during the design phase. During Step 1, the planning phase, of our professional development event university faculty members gathered feedback from program participants on challenges they faced during the prior academic year. Early career high school math teachers expressed frustration at the lack of good materials that were classroom ready and aligned to the common core content objectives. They found an abundance of free online curricular materials, but became overwhelmed with the time it took to sort through the plethora of materials in an attempt to find high-quality lessons that were aligned to the common (CCSS) objectives. There were many topics that were identified by teachers as topics that they wanted help with. The most common content area of concern was finding materials to teach probability including real-world modeling of these concepts.

We found that step 2 in the design phase, 'identifying the Common Core Standards that aligned with the topic', was a relatively easy task for early career teachers, but translating the objective into meaningful and high-quality lessons was a big challenge. Participants quickly accessed the CCSS objectives online and accurately identified the high school probability objectives as:

> Conditional Probability and the Rules of Probability. Students will understand independence and conditional probability and use them to interpret data. Students will use the rules of probability to compute probabilities of compound events in a uniform probability model. Using probability to make decisions: Students will calculate expected values and use them to solve problems and use probability to evaluate outcomes of decision (Common Core Standards, pp. 82-83).

There was an abundance of resources available to complete the 3-day face-to-face professional develop activities including: computers with internet access, research articles, sample curriculum models, and consumables. Participants provided their own computers and university provided internet access when participants were on campus. By the end of the third day of the face-to-face component of the PD, participants had created a fairly robust draft of instructional materials for teaching probability. There were times when participants would disagree about what to include in the unit. After a brief discussion, participants agreed to categorize materials by: developing students' conceptual understanding; real-world applications; developing procedural fluency; extensions to the topic; and formal assessments. Teachers were unanimous in their desire to have something simple and easy to read without long extensive instructions for each activity.

Participants who attended the face-to-face PD shared the materials with colleagues at their individual schools by providing access to materials through online document sharing or email. University faculty members followed up with participants throughout the school year as materials were being implemented in the classroom. One of the challenges encountered with this model was getting meaningful feedback from the crowd. Many teachers "in the crowd" requested access to documents but relatively few provided feedback after implementing with students. Providing some type of incentive may increase the number of teachers who would take the time to provide feedback.

EVALUATION

At the conclusion of the professional development, participants were asked to evaluate the PD using an open-ended survey. The purpose of the evaluation was to determine the extent to which *Designing Mathematics Instruction utilizing Crowd-sourcing* met its project goals and objectives to: 1) determine if Crowdsourcing is an effective model of PD; 2) promote collaboration between high school mathematics teachers locally and statewide; 3) increase higher education faculty member engagement in the development of classroom materials that are aligned to the common core standards for mathematics. The evaluation plan consisted of both formative (ongoing monitoring of project activity) and summative (identifying the degree to which measurable objectives and outcomes are met) measures. To this end, program evaluation was based on responses from participants who were asked to participate in an open-ended survey that measured the impact of this form of professional development on their classroom instruction. Program staff, with the assistance of a graduate student, developed the survey instrument, collected data, analyzed the data, and provided a summary report of findings that highlighted program strengths, identify challenges, and consider unexpected outcomes.

Research Questions included:

- What change(s) did you make to your classroom instruction based on the professional development you received?
- What impact do you think this PD had on your students' mastery of the (Probability) concepts you taught?
- What impact did this PD have on your own knowledge of teaching Probability?

A SUMMARY OF RESULTS

Results from this project gave an indication that crowdsourcing has potential to be a good strategy for teacher professional development, but has some limitations that others need to be aware of in terms of implementation planning.

Key Findings:

- This form of PD increased higher education faculty members engagement in the development of classroom materials that are aligned to the common core standards for mathematics;
- Promoted collaboration between early career high school mathematics teachers and university faculty;
- Engaging faculty and teachers in this new form of PD helped both groups to better understand the complexities of the classroom and to work together to find solutions.
- Participants from different school districts came with different expectations for student outcomes and had access to different curricular materials.
- Teacher participants found it valuable to select the curriculum topics.
- Participants found it valuable for university faculty members to provide the curricular materials and to model how to implement and assess student mastery.
- Teachers were successful at revising materials based on their students needs but did not have time to develop their own instructional materials.
- When it was time to field test materials with students in their classrooms there was inconsistency in those who followed through with classroom implementation and feedback.
- All teachers who participated in the face-to-face portion of the PD made changes to their classroom instruction and reported an increase in math content knowledge.
- The impact on students' knowledge of probability was difficult to measure. Teachers reported that they found students more engaged in classroom activities using the newly developed unit of instruction compared to previous students taught.

Some challenges delivering this type of PD occurred during the implementation phase and included the following. Teachers were teaching in different school districts so the unit of instruction was taught at different locations and at different times. Some were on a four-period, semester long schedule, while others were on a seven-period, year-long schedule. The crowdsourcing process is time consuming, but resulted in a high quality unit of instruction that teacher found valuable. Teachers expressed some disappointment that they did not receive the entire years' worth of similar materials. Recommendations for others who may want to try this model: when utilizing crowdsourcing as a PD model, select different size groups. For steps 3, 4 and 5 invite a small crowd of approximately 5 teachers then expand the size of the crowd for steps 6, 7, and 8 to get a broader perspective. For steps 3-5 teachers need to be skilled at writing and developing units to take the lead on the first draft before sending it out to a larger crowd for feedback. This type of professional development requires an extensive amount of time for participants to complete steps 3-5 and a strong level of commitment to implement. It was a challenge to get feedback from some of the participants. Providing stipends to those who attended the 3-day face-to-face component and those who provided online feedback on the unit is recommended.

Overall, this type of PD has potential to be effective with a larger group of participants. Comments from the first group of participants included “this was the best PD I have participated in” and “it was nice to have someone listen to us [teachers] and value our opinion for how classroom instruction should be designed.” Further study is needed to determine if this type of professional development works with different content areas. It would also be interesting to find out if the relationship developed between the participants who attended the face-to-face professional development sessions had any impact on their eagerness and commitment to change their own teaching practices.

REFERENCES

Ball, D.L., Hill, H. (2009). The curious - and crucial - case of mathematical knowledge for teaching. Phi Delta Kappan, 91(2), 68-71.

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher, 33* (3), 3-14.

Clark, C. and Florio-Ruane, S. (2001). Conversation as support for teaching in new ways. In C.M. Clark (Ed.), *Talking Shop: Authentic Conversation and Teacher Learning*. New York: Teachers College Press, pp. 1-15.

Common Core State Standards for Mathematics (2010). Washington, D.C.: Council of Chief State School Officers and National Governors Association. Retrieved April 1, 2012 from http://www.corestandards.org/in-the-states

Crowdsourcing. (2014). In Merriam-Webster.com. Retrieved May 8, 2014, from http://www.merriam-webster.com/dictionary/crowdsourcing

Ferguson, R. (2006). Five Challenges to Effective Teacher Professional Development, Retrieved from http://www.center-school.org/downloads/ChallengesEffectiveProfDev.pdf June 20, 2013.

Garet, M., Porter, A., Desimone, L., Birman, B., Suk Yoon, K. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal, 38* (4), 915-945.

Graziano, C. (2005). Public Education Faces a Crisis in Teacher Retention. Retrieved from http://newteacher.com/pdf/SchoolsOutPublicEducationFacesaCrisis.pdf on June 20, 2013.

Grossman, P., Wineburg, S., & Woolworth, S. (2001). Toward a theory of teacher community. Teachers College Record, 103, 942-1012.

Hill, H. (2009). Fixing Teacher Professional Development, *Phi Delta Kappan*, Vol. 90, No. 07, pp. 470-477.

Ingersoll, R. M. (2001). Teacher turnover, teacher shortages, and the organization of schools (No. R-01-1). Seattle: University of Washington, Center for the Study of Teaching and Policy.

Ingersoll, R. M. (2003). Is there really a teacher shortage? Seattle: University of Washington, Center for the Study of Teaching and Policy.

Klinger, J. K. (2004). The science of professional development. *Journal of Learning Disabilities*, 37(3), 248–255.

Lieberman, A. (1995). Practices that support teacher development: Transforming conceptions of professional learning. *The Phi Delta Kappan, 76*(8), 591-596.

Little, J. (1993). Professional development in a climate of educational reform. *Educational Evaluation and Policy Analysis, 15* (2), 129-151.

Nieto, S. (2003). What keeps teachers going? New York: Teachers College Press.

Robinson, R., Carrington, S. (2002) "Professional development for inclusive schooling", *International Journal of Educational Management*, Vol. 16 Iss: 5, pp.239 – 247.

Science Buddies. (2015). Comparing the Engineering Design Process and the Scientific Methods. Retrieved from http://www.sciencebuddies.org/engineering-design-process/engineering-design-compare-scientific-method.shtml, March 2, 2015.

Smith, T. M., & Ingersoll, R. M. (2004). What are the effects of induction and mentoring on beginning teacher turnover? American Educational Research Journal, 41, 681–714.
Swenson J. (2003). Transformative teacher networks, on-line professional development, and the write for your life project. *English Education, 35*(4), 262-321.
Wilson, S. and Berne, J. (1999). Teacher learning and the acquisition of professional knowledge: An examination of research on contemporary professional development. *Review of Research in Education, 24,* 173-209.

APPENDIX A

Common Core Standards
http://www.corestandards.org/Math/Content/HSS/CP/

Understand independence and conditional probability and use them to interpret data
CCSS.MATH.CONTENT.HSS.CP.A.1 Describe events as subsets of a sample space (the set of outcomes) using characteristics (or categories) of the outcomes, or as unions, intersections, or complements of other events ("or," "and," "not").

CCSS.MATH.CONTENT.HSS.CP.A.2 Understand that two events *A* and *B* are independent if the probability of *A* and *B* occurring together is the product of their probabilities, and use this characterization to determine if they are independent.

CCSS.MATH.CONTENT.HSS.CP.A.3 Understand the conditional probability of *A* given *B* as *P* (*A* and *B*)/*P* (*B*), and interpret independence of *A* and *B* as saying that the conditional probability of *A* given *B* is the same as the probability of *A*, and the conditional probability of *B* given *A* is the same as the probability of *B*.

CCSS.MATH.CONTENT.HSS.CP.A.4 Construct and interpret two-way frequency tables of data when two categories are associated with each object being classified. Use the two-way table as a sample space to decide if events are independent and to approximate conditional probabilities. *For example, collect data from a random sample of students in your school on their favorite subject among math, science, and English. Estimate the probability that a randomly selected student from your school will favor science given that the student is in tenth grade. Do the same for other subjects and compare the results.*

CCSS.MATH.CONTENT.HSS.CP.A.5 Recognize and explain the concepts of conditional probability and independence in everyday language and everyday situations. *For example, compare the chance of having lung cancer if you are a smoker with the chance of being a smoker if you have lung cancer.*

Use the rules of probability to compute probabilities of compound events.
CCSS.MATH.CONTENT.HSS.CP.B.6 Find the conditional probability of *A* given *B* as the fraction of *B*'s outcomes that also belong to *A*, and interpret the answer in terms of the model.

CCSS.MATH.CONTENT.HSS.CP.B.7 Apply the Addition Rule, P (A or B) = P (A) + P (B) - P (A and B), and interpret the answer in terms of the model.

CCSS.MATH.CONTENT.HSS.CP.B.8 (+) Apply the general Multiplication Rule in a uniform probability model, P (A and B) = P (A) P (B|A) = P (B) P (A|B), and interpret the answer in terms of the model.

CCSS.MATH.CONTENT.HSS.CP.B.9 (+) Use permutations and combinations to compute probabilities of compound events and solve problems.