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Practice-based pedagogy in mathematics and science teaching methods: Challenges and adaptations in context

Just over five years ago, conversations between mathematics and science teacher educators in our faculty led to considerations of how to develop a more consistent pedagogical approach to teacher education across subject areas and programs. The conversations included a discussion of Cycles of Enactment and Investigation (Kazemi, Franke, & Lampert, 2009), an approach to teacher education which had already shown promise in terms of supporting novice teachers in understanding the complexities of teaching (Lampert et al., 2013). In what follows, we describe our own practices as mathematics and science teacher educators, and our collaborative efforts to develop novice teachers' pedagogies of practice in three complex and varied teacher education programs via Cycles of Enactment and Investigation. More specifically, we present some of the challenges we have encountered with respect to implementing Cycles in our own academic context, along with how we have adapted the Cycle to support novice teachers within the context of our own programs. We offer this work as an introduction to Cycles of Enactment and Investigation in a Canadian setting, as well as an example of how programs developed elsewhere might be adapted to more local contexts.

Research indicates that novice teachers frequently leave teacher education programs with a great deal of theoretical knowledge about effective mathematics or science teaching, but scant opportunities to practice these pedagogies in context (Grossman, Hammerness, & McDonald, 2009; Windschitl, 2006). The result in the field is that novice teachers enact a mixed bag of pedagogical approaches (Windschitl, 2006). These can range from inquiry-based methods, to rote methods formulated through the "apprenticeship of observation" - the lengthy process of enculturation into beliefs about teaching that novices have engaged in throughout their lives as students (Lortie, 1975). Over the past five years we have been developing a program of mathematics and science teaching that requires novice teachers to enact core practices (McDonald et al., 2014) that elicit and respond to students' thinking. To develop

these practices, we have integrated the Cycle of Enactment and Investigation (Kazemi et al., 2009) within each mathematics and science methods course. The Cycle requires novice teachers to observe modeled instructional activities, to plan instruction based on those activities, to rehearse the activities with their peers, and ultimately to enact these instructional activities in context with students.

Our use of the Cycle of Enactment and Investigation is based on the pedagogies of practice introduced by Kazemi et al. (2009) to support novice mathematics and science teachers in learning to teach "in response to what students do" (p. 11). In this approach, novice teachers and teacher educators (in our case, faculty members, course instructors, and teaching assistants) engage in modeling and rehearsal of instructional activities designed to support content learning while eliciting students' ideas and encouraging various forms of classroom discourse.

Cycles of Enactment and Investigation

Cycles of Enactment and Investigation are repeated routines that provide opportunities for novice teachers to both practice teaching and reflect on that practice. They are organized around a set of teaching practices that are likely to yield improvements in K-12 student learning, but are also accessible to novice teachers in terms of learning to teach (Ball, Sleep, Boerst, & Bass, 2009; Windschitl, Thompson, Braaten, & Stroupe, 2012). These practices, referred to as high leverage, ambitious, or core practices, vary depending on the teacher education program. In general, they include larger aspects of the work of teaching, such as planning instruction, as well as components of the interactional work of teaching (what we refer to as *discourse moves*), such as eliciting and responding to students' thinking or representing students' thinking during class discussions (e.g., Thompson, Windshitl & Braaten, 2013). In addition to high leverage practices, Cycles of Enactment and Investigation focus on a set of principles about the nature of teaching and learning that are intended to guide novice teachers in their use of the practices (Lampert et al., 2013). For example, principles include "treating students as sense-makers," articulating "clear instructional goals to guide instruction," and ensuring all students "have equitable access to

rigorous academic work" (Lampert et al., 2013, p. 228). Because disciplinary content is at the heart of teaching, principles and practices are also considered in relationship with the content knowledge of specific subject areas (Lampert et al., 2013).

Cycles of Enactment and Investigation are also organized around carefully designed instructional activities (Kazemi et al., 2009; Lampert, Beasley, Ghousseini, Kazemi, & Franke, 2010; Lampert & Graziani, 2009). In teacher education programs, instructional activities are intended as tools for novice teacher learning, although these same activities may be subsequently used as lessons for teaching K-12 students. The activities are designed to expose high leverage practices in ways that are explicit and accessible to the novice teachers, while simultaneously enabling them to support their own students' developing understandings in subject area content. The activities tend to vary based on subject area. In mathematics, instructional activities can range from brief warm-up routines to the longer components of a lesson (e.g., Kazemi et al., 2009). In science, instructional activities are generally introduced as phenomena that will drive a learning situation and are often discrepant events that can be used to elicit students' ideas about phenomena in order to generate model-based explanations (Windshitl, Thompson, & Braaten, 2008). Generally, the instructional activities that are selected to initiate the cycle are modeled by teacher educators to make explicit reference to their own practices and underline, for example, discourse moves they are using to elicit students' thinking or to facilitate classroom talk.

Based on Lampert et al.'s (2013) model, we have adapted the Cycle of Enactment and Investigation such that each iteration is composed of the following six steps: (1) modeling, (2) collective planning, (3) rehearsal, (4) reflection, (5) enactment, and (6) final reflection. In *modeling*, novice teachers observe an instructional activity within a classroom, either by watching a pre-recorded video or by watching an experienced teacher. In *collective planning*, novice teachers, along with the teacher educator, collectively analyze the modeled teaching in order to make sense of the ways in which principles, practices, and content were used in the instructional activity. Novices then use a protocol to plan to teach the

instructional activity to a group of students. The protocol is a document that novices draft as they plan their activity. In the protocol, they list a long, detailed set of procedures (including specific questions they will ask, responses they will have for anticipated student questions, methods for representing students' ideas on whiteboards, and methods for orienting students to each others' thinking). The protocol is drafted for submission ahead of the rehearsal, and is then put into use during the rehearsal. In the third component, novice teachers practice or *rehearse* the instructional activity in a simulation where their university peers play the role of the targeted grade level of students. Unlike other simulation models, such as microteaching (Fernandez & Robinson, 2006), rehearsals provide the ability to "pause" or interject to allow teacher educators and novice teachers to exchange questions, suggestions, and reflections about teaching as it unfolds (Lampert et al., 2013; Pfaff, 2013). In this setting, the teacher educator plays the role of "coach" to provide guidance to the novice teacher by giving directive feedback, such as suggesting a next teacher action, or by giving evaluative feedback, such as highlighting more or less productive moments for supporting student learning (Lampert et al., 2013). In addition, teacher educators may step in during interjections to model how the novice teacher might teach in the moment or might play the role of a student in order to present new situations for the novice teacher to respond to (Lampert et al., 2013). The teacher educator may also seize opportunities to involve other novice teachers in a discussion about more general issues of teaching (Lampert et al., 2013). Rehearsals are video-recorded and novice teachers are asked to *reflect* on their rehearsal in the fifth step of the cycle. After the reflection, novice teachers reteach or *enact* the same instructional activity to a group of school-aged children. The enactment is video recorded. The recording serves as the basis for the *final reflective* analysis of teaching, again with a focus on principles, practices, and content.

As we are implementing Cycles of Enactment and Investigation across mathematics and science methods courses at different levels of instruction (elementary and secondary), we have found that we have had to modify the process to respond to the particular needs of our instructional contexts. In the sections

that follow, we first describe our teacher education programs to provide context to these modifications, and then how we adapted the Cycle into our elementary and secondary mathematics and science education courses.

Context

In our faculty, we have three teacher education programs; two at the undergraduate level and one at the graduate level. Our 4-year Bachelor of Education (B.Ed.) offers streams for elementary and secondary certification, and our 18-month Master of Arts in Teaching and Learning (MATL) solely provides secondary certification. At the elementary level, novice teachers complete two methods courses in all core disciplinary areas (e.g., mathematics, science, language arts, and social studies); at the secondary levels, novice teachers complete two methods courses in their major teaching discipline (mathematics or science).

The programs differ in terms of numbers of students and how courses are structured. The secondary cohorts in both the B.Ed. and MATL programs are the smallest, ranging from 9-20 students per subject and program per year. The elementary cohort is larger at around 120-150 students per year. In the mathematics courses, elementary novice teachers are divided up into three or four sections of approximately 30-45 students each. Teaching assistants (TAs) are hired to support the course instructors during the cycle of enactment and investigation. The elementary science methods course is structured around a lecture and lab format. Each week, the entire cohort attends a lecture given by the course instructor and a lab component in smaller groups (~26 students). Labs are facilitated by graduate student TAs.

B.Ed. students complete four practice teaching placements (practica) of varying lengths throughout their programs, typically one per year. None of the practica overlap with methods courses. This is in contrast to MATL students whose two full-semester practica occur concurrently with methods

courses, one in each year of their studies. Thus, MATL methods courses are offered as evening classes taken after a day of teaching in schools.

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Considerations for Incorporating Cycles of Enactment & Investigation into Teacher Education Programs

Given the different contexts of our teacher education programs, a number of considerations for incorporating Cycles of Enactment and Investigation have arisen. We have found that these considerations tend to occur in relation to four of the Cycle's six steps: modeling, collective planning, rehearsals, and enactments.

Modeling and Collective Planning

While Lampert et al. (2013) list modelling and collective planning as two separate steps within the Cycle, modelling is often almost immediately deconstructed and analyzed in order to support novice teachers in their collective planning. As such, we consider modelling and collective planning together in this instance. In general, as teacher educators we model expert practice every time we teach. However, this phase of the cycle requires us to be very explicit about our pedagogy, and to model very specific instructional activities designed to demonstrate the practices we are using. Following the modeling of practice comes collective planning (specifically, protocol planning). In some cases, planning comes immediately after modeling, and rehearsals happen quickly after planning. This poses considerable logistical challenges which will be elaborated on in the next two sections.

Timing and logistical considerations. One of the key challenges we face in all courses revolves around timing and logistics. To allow each novice teacher to engage in a full Cycle of Enactment and Investigation requires a minimum of eight weeks in a 13-week term. In the first methods courses in all programs, time is further compressed by the need to first develop shared language around teaching and learning. In these first courses, we find at least some students having to begin the Cycle of Enactment and Investigation process before they have a complete introduction to the entire process.

At the elementary level, the logistical tensions of the first methods courses are further complicated by the need to teach content and pedagogy in concert, by the necessity to address novice

teachers' mathematics and science anxiety, by the size of the cohort, and by novice teachers taking both mathematics and science methods courses in the same term. For example, in the first methods course in elementary science, two different lessons are modeled so that novice teachers may develop protocols for their own lessons. While novice teachers may choose either lesson, both have downsides: one is presented near the beginning of term before all elements of the Cycle of Enactment and Investigation have been discussed in-depth, the second is presented slightly after mid-term and leaves novice students with a compressed timeline for completing all elements of the assignment. To balance some of these inequities, novice teachers who choose to use the first lesson for their assignment are presented with a complete sample protocol that they must personalize in terms of questioning, wording etc. Novice teachers who choose to use the second lesson must develop most of the protocol themselves–although a full example of what the lesson might look like is provided in their lab manuals.

Protocol writing and feedback. When novice teachers develop protocols for their lessons, teacher educators are required to provide feedback that will guide the novice teachers as they prepare for their rehearsals.

Elementary courses. At the elementary level, the primary challenge is related to student experience. In most cases, the protocol exercise is the first time in the program that novice teachers engage in any kind of planning for instruction, and so constructive feedback on the protocol prior to rehearsals is crucial. In the elementary science program, we scaffold protocol writing over the two terms, so that in the first term the students need only to indicate their instructional goals and to develop discourse moves they will make to meet those goals, using the instructional activity assigned. Feedback on this assignment is focused on the kinds of discourse moves the novice teachers propose to make, how these moves will help to elicit students' thinking, and how they will guide students towards the instructional goals. The second semester gives more agency to the novice teachers in terms of planning. They are given a choice of two topics and have to develop a 5E (Biological Sciences Curriculum Study &

International Business Machines, 1989) lesson in small groups. Feedback in the second planning exercise focuses on the alignment with instructional goals throughout the lesson, connection to the provincial program of study, as well as on the discourse moves and representations of students' ideas that will lead the class to collecting data which allows for evidence-based explanations. The timing of this feedback in the elementary science courses is crucial, as students are expected to incorporate comments and suggestions into their protocol before their rehearsal. They are given the opportunity to revise the protocol again after the rehearsal.

Challenges related to novice teacher experience are mitigated in elementary mathematics methods in two ways. In the first methods course, novice teachers are provided with a completed protocol that they need to practice but not plan. They enter the second course after having completed three practica. At this stage, novice teachers are more able to understand what teaching looks like in a classroom setting and so are better able to engage in protocol development.

Secondary courses. One place where we have significantly adapted the Cycle of Enactment and Investigation is in our secondary programs. Here, instead of modeling specific instructional activities that novice teachers then repeat, teacher educators model the core practices of high quality teaching and novice teachers select their own activity to rehearse/enact. The reason for this shift is two-fold. First, with smaller class sizes we felt that unique activities are manageable, allowing novice teachers to engage with the process of creating an activity of personal interest. Second, MATL novice teachers are concurrently in practica, thus we felt that they could benefit from rehearsing an activity that they could potentially enact in their own teaching. The choice of instructional activity means that when novice teachers submit their protocols, we are faced with navigating the variety and scope of their chosen activities and providing feedback to ensure that the novice teachers are on track in their rehearsal preparations.

In secondary mathematics, we scaffold novice teachers' development by having them complete an assignment prior to engaging in the Cycle of Enactment and Investigation in which they create a

mathematics activity inspired by an article from a professional journal. A goal of this assignment is to develop the novice teachers' ability to create student-centered activities. The teacher educator provides specific feedback to novice teachers focused on how their structuring of the activity may or may not support students' developing mathematical thinking. This feedback frequently focuses on the manner in which the activity is ordered, how teachers and students interact during the activity, or how students may interact with each other. Thus, by the time the novice teachers submit the protocols for their rehearsals, they will have already had some experience planning instruction in line with the practice-based approach to teaching. To spread out the workload in the course (as the previous assignment has only been completed some weeks prior), we allow the novice teachers to submit their protocols relatively close to their rehearsal. For B.Ed. novice teachers, they submit their protocols four days prior. Acknowledging that it can be difficult for the MATL novice teachers to know in advance the topics that they will be teaching in their practicum around the time of their rehearsal, we allow the novice teachers to submit their protocols as close to the rehearsal as possible, only 48 hours in advance.

In secondary science, we also have a multi-layered approach, but in contrast to secondary mathematics where multiple assignments scaffold novice teachers' learning, scaffolding occurs within the Cycle of Enactment and Investigation. In the first methods course, we scaffold novice teachers' completion of their protocols through multiple steps: situating a lesson within a big idea (Harlen, 2010), developing an anchoring activity, driving question, etc. Each stage builds on and includes the previous stages. At each stage, the teacher educator provides feedback that novice teachers are expected to account for in the subsequent stages. By the time they submit the full protocol they have received two or three iterations of feedback on some sections of the piece. In the second secondary methods course, novice teachers work in pairs and there is significantly less scaffolding prior to submission of protocols. Novice teachers still receive substantial feedback, but this time from both the teacher educator and their peers. Each novice teacher receives two of their peers' protocols for review, and is expected to draw on

understandings developed in the first methods course to critique and provide feedback on the lesson. Based on the size of the cohort, pairs generally receive feedback from five people (four peers and the teacher educator). They then take the feedback, make changes to the protocol, and test the activity around which the protocol is based in class. Additional changes to the protocols emerge from testing. By the time they rehearse, the protocol has undergone two sets of review and feedback from multiple sources.

Rehearsals

Given the variety of class sizes and the limited time we have in labs, scheduling and coaching rehearsals pose another significant logistical challenge. Here we describe the limitations posed by large class sizes and the difficulties of creating an environment for authentic practice with groups of adults in a teaching lab context.

Limitations of large class sizes. Our classes and labs range in size from 9-44 novice teachers. For the larger elementary classes and labs, one challenge has been how to provide time for each novice teacher to participate in a rehearsal. Given the benefit of having someone to facilitate the rehearsals (Kazemi, Ghousseini, Cunard, & Turrou, 2016; Lampert et al., 2013; Pfaff, 2013), we wanted to ensure that a teacher educator would be present for each novice teacher's rehearsal. Thus, for the elementary classes, we adapted in two ways. First, we limited rehearsal time for each novice teacher to approximately 7-9 minutes. In this time, novice teachers are only able to rehearse a portion of the instructional activity. Second, we have hired TAs in order to split the classes and labs into two. Half the class rehearses with the instructor and half with the TA, allowing us to have more rehearsals within the same amount of time.

Constructing authentic rehearsal experiences. Grossman and colleagues (2009a, 2009b) describe the importance of providing novice teachers with approximations of practice to support their development. We provide these opportunities through rehearsals, but one of the challenges that we face is creating a context in our rehearsals that closely mirrors what the novice teachers will encounter in their enactment or their future teaching. Whereas in the secondary methods courses it is less of a stretch for

novice teachers to "approximate" their role as secondary school students as they are closer in age, in the elementary courses, it is more challenging for novice teachers to accurately portray students' thinking. Our elementary novice teachers take their first methods courses (mathematics and science) in the fall of year two of their four-year program. At this point in their program, they have had only one two-week practicum in which they observed classroom routines. While some novice teachers enter the program with experience working with youth (e.g. as camp counselors, or through tutoring), many have had no experience working in school contexts. Thus, when it comes time for the novice teachers to act as "students" for their peers' rehearsals, many of them do not have the experience or knowledge to accurately portray the role of an elementary student. The novice teachers are simply unable to respond to the "teacher" in a way that mirrors how an elementary student would respond.

To support the "students" in their role (and ostensibly, to support the "teachers" in their rehearsal), within our elementary methods courses we have created cue cards with "student profiles" and suggestions on how the student may respond to the teacher. In these profiles, we describe what the student understands, some challenges/alternative conceptions that he/she may have, and suggestions of how the student might progress through the instructional activity (e.g., having specific misunderstandings at the beginning, but through specific prompts or experiences, will grasp the material by the end). In elementary mathematics, we also provide suggestions for types of discourse to approximate how students might articulate their mathematical thinking. For example, some cards suggest particular language that students might use or suggest that the "student" should have trouble articulating his/her thinking.

Enactments

Enactments have specific challenges primarily because they occur outside of the university context. Instructors have little control over the contexts for enactments, and less ability to directly support students in adapting to those contexts. In what follows, we describe some of these challenges, and the steps that we have taken to mitigate them when possible.

Gaining access to students. One of the biggest challenges we have encountered has been acquiring access to students for the novice teachers to enact the lessons that they rehearsed. Typically, in the Cycle of Enactment and Investigation, novice teachers complete enactments in schools to create a closer approximation to practice (Grossman et al., 2009a). Without a strong affiliation with partner schools, our novice teachers are required to use their pre-existing contacts with local schools, after school programs, or extracurricular programs (often from their own schooling as elementary or secondary school learners, or from previous practica) to create opportunities for enactments. While local novice teachers can usually find an appropriate group of students to work with through family, friends, or personal school connections, novice teachers from out of town have a harder time meeting this requirement. As such, we allow novice teachers to conduct their enactments with adults provided the enactment participants are not mathematics nor science teachers and have not previously taken the course in which novice teachers are registered.

To provide a context in which the adult "students" may more authentically respond like students, for the mathematics course, novice teachers facilitate activities with mathematics content that will provide some challenge for adults. In science courses, it has not been as necessary to adjust activities for use with adults in enactments; in general, activities focus on applications of science in everyday life and so the activities can be just as, if not more, challenging for adults as for students in the appropriate grade. While the novice teachers are still able to use their practices of high quality teaching in such enactments, as future teachers, they are missing out on developing these practices with a group of students whom they will work with in the future.

Enactments can be disruptive. Unlike rehearsals, enactments can provide novice teachers with closer approximations to practice. However, the increased authenticity of the context also intensifies the complexity that novice teachers need to manage when teaching, making it challenging for novice teachers to focus on and develop aspects of their teaching practice (Grossman et al., 2009a). For many of our

novice teachers, this is their first time teaching elementary or secondary school students. Thus, in order to help reduce complexity, we ask the novice teachers to work with small groups of students, between 4-10 depending on the course.

However, as schools have various priorities and constraints, we have encountered an additional challenge–many are not able to accommodate class disruption through the removal of a small groups of students for the durations of the enactment. In response, we have allowed the novice teachers to conduct their enactments with the whole class.

Seeking permissions for video recording. As enactments are to be video recorded, one challenge has been to ensure that novice teachers have permission to do so. Without a partner school, where such permissions could be established by the faculty members, novice teachers must seek permission on their own. We thus provide novice teachers with letters that inform schools, administrators, cooperating teachers, and parents of what will take place, the purpose of the enactment, and how the video will be used. Where necessary we also provide novice teachers with consent forms for parents/guardians to sign. The need for consent varies considerably; some schools have blanket consent forms that parents sign at the beginning of the year, others require consent for each intervention. In all cases, we specify to the novice teachers that they are to position the video camera so as to protect the identity of the students. If students become visible in the frame (e.g., students coming to the front of the class to explain something to his/her peers) they are to adjust camera framing so that student work can be seen, but the student is not identifiable; where framing cannot or is not adjusted, novice teachers edit out that piece of the video after transcribing what was said and describing student work.

Fitting enactments into practica. We are aware that enactments contribute to the heavy workload of practica for novice teachers who are in our MATL Program. We have chosen to make the enactment portion of the Cycle of Enactment and Investigation optional for the secondary mathematics and science methods courses in the MATL for this reason. So, while rehearsals are still required for all

novice teachers, a variety of options are offered for those who choose not to complete the enactment. In secondary science methods, one option is for novice teachers to keep a journal focused on observed examples of high leverage practices within their practicum and then produce a reflective paper that considers these observations in relation to class readings and discussions. Accordingly, the grading of the Cycle of Enactment and Investigation is weighted differently based on the components that are completed.

Closing Thoughts

Given the complexity of teaching, as our novice teachers engage in Cycles of Enactment and Investigation to refine their practices, we (teacher educators) also engage in this deliberate and reflective approach. Thus, we end this paper not with hard and fast conclusions, but with thinking in progress.

As a teacher preparation tool, we have found that the use of pedagogies of practice have greatly enhanced our teaching model. In our mathematics and science methods classes, we focus on approximations of practice (Grossman et al., 2009b) through the Cycle of Enactment and Investigation. This fine-grained focus on modeling of instruction, breaking down teaching practice into its component parts, rehearsing, and subsequently enacting activities appears to be supporting most novice teachers in our programs in developing a reflective practice that allows them to refine their own teaching. At the same time, we have learned that a number of structural features in our programs constrain our practice and the implementation of the Cycle of Enactment and Investigation. In responding and adapting to these constraints, we draw on one of the principles we hope our students will come to understand, that all "teachers must be responsive to the requirements of the school environment" (McDonald et al., 2014, p. 503). For our purposes, as teacher educators, we have had to respond to the specific requirements of teaching with a school environment of teacher education programs in a post-secondary institution. In this paper, we have therefore provided examples of how we have adapted the Cycle of Enactment and Investigation so that other mathematics and science teacher educators can learn from our experience. For

our novice teachers, it is clear that there is more work to be done, as we have largely not been successful in providing opportunities for "real life" enactments, with non-adult students. Thus, we continue to endeavour to heed this principle, and acknowledge the difficulty of providing "authentic" environments for rehearsal situations in our teacher education program.

As we have discussed, in our own context, significant adaptations to the Cycle of Enactment and Investigation have been required to accommodate practica, large class sizes, and the multiple and varying contexts of enactment sites. Across all the courses, we have found that the planning and rehearsal portions of the Cycle are resource intensive and require many "hands-on-deck" to support novice teacher learning. We recognize that our teacher educators (faculty members, course instructors, and TAs) play a significant role in novice teacher development, yet have a range of experiences, understanding, and comfort with the Cycle of Enactment and Investigation. Thus, the challenges and adaptations that we have identified also raise questions for potential research trajectories. For example, we are currently exploring ways in which we may support new(er) teacher educators in developing their experience with practice-based pedagogies. While, some of our faculty and graduate students are currently investigating the learning of teacher educators with respect to facilitating aspects of the Cycle of Enactment and Investigation, additional research is needed to better provide supports for others wishing to implement this model. In addition, future research might investigate the nature of learning opportunities for novice teachers in the different adaptations, such as enactments with adults or rehearsals using novice teachers' own lesson plans. We are also interested in novice teachers' growth and experiences of the Cycle of Enactment and Investigation over the span of the two methods courses taken per subject area within our programs.

As we continue this work, what we find most promising about the approach we have adopted is the coherence it creates within our mathematics and science programs. From one course to another, across subject areas in the elementary program and across the sequence of the two methods courses in the two secondary programs, our novice teachers have repeated opportunities to develop and reflect upon their

teaching practice. We continue to refine our approach to provide a consistent structure for our novice teachers to develop practices that will lead them to become effective mathematics and science teachers.

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References

Ball, D. L., Sleep, L., Boerst, T., & Bass, H. (2009). Combining the development of practice and the practice of development in teacher education. *Elementary School Journal*, *109*(5), 458-474.

Biological Sciences Curriculum Study & International Business Machines. (1989). *New designs for elementary science and health: A cooperative project between Biological Sciences Curriculum Study (BSCS) and International Business Machines (IBM)*. Dubuque, IA: Kendall/Hunt Publishing Company.

Fernandez, M. L., & Robinson, M. (2006). Prospective teachers' perspectives on microteaching lesson study. *Education*, *127*(2), 203-215.

Grossman, P., Compton, C., Igra, D., Ronfeldt, M., Shahan, E., & Williamson, P. (2009). Teaching practice: A cross-professional perspective. *Teachers College Record*, *111*(9), 2055-2100.

Grossman, P., Hammerness, K., & McDonald, M. (2009). Redefining teaching, re-imagining teacher education. *Teachers and Teaching: Theory and Practice*, *15*(2), 273-289.

Harlen, W. (Ed.). (2010). *Principles and big ideas of science education*. Hatfield, UK: The Association for Science Education.

Kazemi, E., Franke, M., & Lampert, M. (2009). Developing pedagogies in teacher education to support novice teachers' ability to enact ambitious instruction. In Hunter, R., Bicknell, B., & Burgess, T. (Eds.). *Crossing divides: Proceedings of the 32nd annual conference of the Mathematics Education Research Group of Australasia*, (Vol. 1, pp. 12-30). Wellington, NZ.

Kazemi, E., Ghousseini, H., Cunard, A., & Turrou, A. C. (2016). Getting inside rehearsals: Insights from teacher educators to support work on complex practice. *Journal of Teacher Education, 67*(1), 18-31.

Lampert, M., & Graziani, F. (2009). Instructional activities as a tool for teachers' and teacher educators' learning. *Elementary School Journal, 109*(5), 491-509.

Lampert, M., Beasley, H., Ghousseini, H., Kazemi, E., & Franke, M. (2010). Using designed instructional activities to enable novices to manage ambitious mathematics teaching. In M. K. Stein & L. Lucan (Eds.), *Instructional explanations in the disciplines* (pp. 129-141). New York, NY: Springer.

Lampert, M., Franke, M. L., Kazemi, E., Ghousseini, H., Turrou, A.C., Beasley, H., … Crowe, K. (2013). Keeping it complex: Using rehearsal to support novice teacher learning of Ambitious Teaching. *Journal of Teacher Education, 64*(3), 226-243.

Lortie, D. (1975). *Schoolteacher: A sociological study*. Chicago, IL: University of Chicago Press.

McDonald, M., Kazemi, E., Kelley-Petersen, M., Mikolasy, K., Thompson, J., Valencia, S. W., & Windschitl, M. (2014). Practice makes practice: Learning to teach in teacher education. *Peabody Journal of Education, 89*(4), 500-515.

Pfaff, E. (2013). Evidence of teacher educator feedback from coaching rehearsals into classroom enactments of ambitious math discussions. Paper presented at the National Council of Teachers of Mathematics – Research Conference.

Thompson, J., Windschitl, M., & Braaten, M. (2013). Developing a theory of ambitious ambitious early-career teacher practice. *American Educational Research Journal*, *50*(3), 574-615.

Windschitl, M. (2006). Sparking the debate over science education reform. *Education Digest: Essential Readings Condensed for Quick Review*, *71*(8), 20-31.

Windschitl, M., Thompson, J., & Braaten, M. (2008). Beyond the scientific method: Model based inquiry as a new paradigm of preference for school science investigations. *Science Education*, 92(5), 941-967.

Windschitl, M., Thompson, J., Braaten, M., & Stroupe, D. (2012). Proposing a core set of instructional practices and tools for teachers of science. *Science Education*, *96*(5), 878-903.