Teaching and Teacher Education 60 (2016) 88–96

Contents lists available at ScienceDirect

Teaching and Teacher Education

journal homepage: www.elsevier.com/locate/tate

Secondary mathematics coaching: The components of effective mathematics coaching and implications

Priscilla Bengo*

Department of Curriculum, Teaching and Learning, Ontario Institute for Studies in Education, University of Toronto (OISE/UT), 252 Bloor Street West, Toronto, Ontario, M5S 1V6, Canada

H I G H L I G H T S

- I explored the elements of mathematics coaching that improve teaching practice.
- These are viewed as the elements of effective mathematics coaching.
- I found the following elements: time, trust, the coach's background and courage.
- I also found that effective coaching required resources and was differentiated.
- Coaching improved instruction.

A R T I C L E I N F O

Article history:
Received 25 October 2015
Received in revised form
16 July 2016
Accepted 22 July 2016
Available online 18 August 2016

Keywords:
Professional development
Coaching (performance)
Mathematics education

A B S T R A C T

Mathematics coaching, which can be defined broadly as job-embedded learning for mathematics teachers with someone who can help, is being used in Canada to improve teaching practice and increase student achievement. Mathematics coaching research is quite new with little written on the components of effective coaching. The paper attempts to contribute to this research. Employing observations, interviews, archival data, and surveys, the study finds that time, trust, the coaches' backgrounds, and their courage in trying new initiatives may be elements of effective coaching. Effective coaching also required resources and was differentiated. Mathematics coaching improved teacher practices.

1. Introduction

Mathematics coaching research is quite new (e.g., Obara, 2010) and coaching means different things to different people (e.g., Grossek, 2008; Horwitz, Bradley, & Hoy, 2011). Cornett and Knight (2008) state that there are several forms of coaching. Therefore, coaching work and hence how mathematics coaching is defined is influenced by the coaching model. The three common mathematics coaching models are cognitive coaching, content-focused coaching, and instructional coaching (Barlow, Burroughs, Harmon, Sutton, & Yopp, 2014). Cognitive coaching (Costa & Garmston, 2002) can be described as a mediation approach to coaching that assumes that an individual's behavior is a result of his or her thought and perception. The coach considers very carefully what a teacher is saying and may employ paraphrasing to help a teacher determine a goal during self-assessment. The coach may also probe to help the teacher attain clarity. A three-phase cycle is used with a pre-lesson conference, a lesson observation, and a post-lesson conference.

Content-focused coaching (West & Staub, 2003) examines students' learning in a particular subject area and a teacher's plan, strategies, and methods to positively influence it. The coach must be able to determine the teacher's needs. The coach looks at a teacher's content knowledge and disposition toward mathematics, pedagogical knowledge, pedagogical content knowledge, and beliefs about learning, as well as the teacher's ability to understand student thinking and the ways teachers use curriculum materials, including planning lessons. Pedagogical content knowledge combines content knowledge of a specific subject and an understanding of how to teach that subject (Shulman, 1987). This form of coaching focuses on designing lessons. Evidence used during coaching consists of student comments, examples of student thinking, student assessment data, and samples of student work, for instance.

* Tel.: +1 416 333 2158.
E-mail address: priscilla.bengo@mail.utoronto.ca.

http://dx.doi.org/10.1016/j.tate.2016.07.027
0742-051X/

Content-focused coaching also employs the three-phase cycle.

Instructional coaching stresses a partnership approach. Knight (2007) suggests seven principles (equality, choice, voice, dialogue, reflection, praxis, and reciprocity) as the theoretical basis for instructional coaching. Specifically, the coachee is treated as an equal by the coach (equality), can select what they learn and how they learn (choice), the teachers know they can reveal their opinions concerning content they are learning (voice), and the coach involves teachers in conversations concerning the content being learned while thinking and learning with them (dialogue). Praxis describes the act of applying new ideas to one's own life, while reciprocity is defined as mutual gain. Like cognitive coaching, instructional coaching depends on the coach's ability to know the teacher's perspective and listen carefully in coaching conversations. A three-phase cycle is used as in the other models. Instructional coaching is concerned with behavior, content, instruction, and formative assessment. In terms of behavior, "teachers need to create a safe, productive learning community for all students. Coaches can help by guiding teachers to articulate and teach expectations, effectively correct behavior, increase the effectiveness of praise statements, and increase students' opportunities to respond" (Knight, 2007, p. 23). Content refers to the content knowledge of the teacher, instruction refers to effective instructional strategies that teachers can use to help students learn and formative assessment should be used by the teacher to determine whether students are learning. The data collected relates to the strategies the coach and teacher are trying. It is important for the coach to emphasize the positive. The models have similarities; an obvious one is the three-phase cycle. Barlow et al. (2014) note that they all have the coach "interacting with teachers about mathematics content, promoting teacher reflection, and negotiating professional relationships between coach and teacher" (p. 228). Based on the models, mathematics coaching can be viewed broadly as a form of professional development for teachers with someone who can help.

Mathematics coaching is used to improve teacher instruction with the intention of improving student achievement in many parts of the world, for example, Australia, the Netherlands, the United Kingdom, Canada, and the U.S. (e.g., Campbell & Malkus, 2014). Many school districts and schools employ it so that teachers can learn in schools or instructional contexts. Campbell and Malkus (2014) state that different forms of coaching are employed in the previously mentioned areas. Mathematics coaching is supported by research that shows a positive impact of coaching on student achievement (e.g., Blank, 2013; Campbell & Malkus, 2010, 2011; Hindman & Wasik, 2012; Neufeld & Roper, 2003; Teemant, 2014). It is also supported by research that demonstrates that a teacher is an important factor in the improvement of student achievement (e.g., Kuijpers, Houtveen, & Wubbels, 2010). Based on these findings, many have concluded that helping teachers enhance their instructional practices will improve student achievement. However, helping teachers to improve instruction is difficult. For example, some teachers are resistant to change because it is not easy to learn the new instructional strategies (Obara, 2010), or because they believe that the new instructional strategies are ineffective (e.g., Bengo, 2013). Some argue that the method of professional development for teachers and its quality can address this issue (e.g., Knight et al., 2015). Specifically, to employ knowledge acquired from workshops or professional development activities in the classroom requires that a qualified person views a teacher's actual instructional practices and gives them feedback (Knight, 2007). This is a rationale for mathematics coaching. Coaching can show teachers how and why certain teaching strategies work (Obara, 2010).

There is an emerging body of research on mathematics coaching that outlines the components of effective coaching. It categorizes them as those concerning the skills of the coach and factors existing in the school and school district. The research shows consistency in terms of the requirements for effective mathematics coaching. For example, the potential components of effective mathematics coaching discussed by Knight et al. (2015), Obara (2010), and Hull, Balka, and Miles (2009) overlap. Specifically, effective communication skills, leadership skills, pedagogical content knowledge, content knowledge, curriculum knowledge and how well a coach is able to work with adults. This research has been developed using various coaching models. It is limited but promising, and therefore warrants investigation (Cornett & Knight, 2008). Obara (2010) and Mudzimiri, Burroughs, Luebeck, Sutton, and Yopp (2014) call for additional research on the components of effective coaching. This study addresses this need as it expands the knowledge base on the components of effective mathematics coaching.

1.1. Components of effective mathematics coaching

Fig. 1 depicts the proposed components of effective coaching from the current literature. The underlying hypothesis is that coaching will improve teacher practice and therefore affect student academic performance.

1.1.1. Qualities of the coach

The qualities of the coach and professional development for coaches are included in the framework for the following reasons. Leinhardt and Greeno (1986) and Smith (1995) noted that a teacher's inability to teach certain topics could be linked to his or her insufficient understanding of the topics. Given this, Obara (2010) argues that effective mathematics coaches need to have a deep knowledge of mathematics content to be able to support teachers with an inadequate understanding of the subject. Even when the coaches have this knowledge, they must ensure that they do not create an expert-novice situation when working with

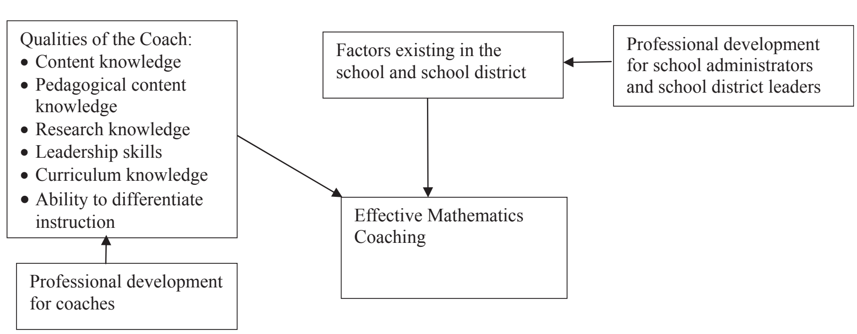

Fig. 1. The conceptual framework.

teachers, as it may have negative effects on the relationship between coach and teacher and therefore on the teacher's learning (Obara, 2010). Coaches may need support that addresses their content knowledge as they help teachers improve instruction (e.g., Chval et al., 2010).

Obara (2010) asserts that mathematics coaches must have pedagogical content knowledge, as they are required to understand how to combine mathematics and pedagogy so that a teacher is able to engage diverse learners and help them understand mathematical concepts. The coach must understand how students learn and know the specific instructional strategies and activities that help students understand concepts; for example, manipulatives, technology, cooperative learning strategies, and various methods of assessment. Cooperative learning strategies can have positive effects on achievement as well as social and psychological characteristics (Kilpatrick, Swafford, & Findell, 2001). Also, connecting assessment and instruction daily increases student knowledge (Black & William, 1998). Knight et al. (2015) argue that “it may be most important that coaches understand how to move through the components of an effective coaching cycle that leads to improvements in student learning” (p. 18). The elements of the coaching cycle are as follows: identify – teacher and coach work collaboratively to determine a goal and a teaching strategy to address it; learn – the coach models the identified teaching strategy so that the teacher can implement it; and improve– the coach monitors the teacher's use of the chosen teaching strategy and whether students attain a goal.

Mudzimiri et al. (2014) show that effective mathematics coaches also require skills to bring the latest research findings into the classroom. Teachers, after all, are required to make research-based decisions that support instruction. According to Hughes (2015), effective coaches know how to collect data, analyze, organize, interpret, and apply it. Data can be employed to show progress, keep educators motivated, inform instructional practice, and ensure that students are learning what they are supposed to.

Neufeld and Roper (2003), Knight (2007) and West and Staub (2003) maintain that coaches must be effective communicators and must have general social skills to establish collaborative relationships. Being able to communicate effectively with teachers as colleagues is an important element of a professional relationship with mutual respect (Knight, 2007; West & Staub, 2003). Mathematics coaches also need to communicate feedback to teachers effectively and must be able to create environments in which teachers and departments can communicate and collaborate (Cataldo, 2013). They may be intermediaries between teachers, administrators, and school district leaders. They can develop positive learning environments in schools by helping teachers address issues that affect them (Obara, 2010). Coaches must have leadership skills to develop such environments (Obara, 2010).

Obara (2010) argues that an effective mathematics coach's knowledge of the curriculum should enable him or her to help teachers link the concepts within a grade and between grade levels. Coaches may need to advise school districts on curriculum selection. In addition, it is likely that the experienced teachers that they help possess understanding about the curricular alternatives that exist (Obara, 2010).The coach may get professional development in this area by enrolling in graduate course work, asking university faculty teaching these courses for help, working with curriculum consultants and attending curriculum summer institutes (Obara, 2010). In general, coaches need to learn continuously as the knowledge of the coach is very important in building teacher knowledge (Hughes, 2015). For example, new challenges develop with time in the classroom. The coach must have sound ways, acquired through continual professional development, to address issues that teachers haven't faced before.

Students have a range of learning abilities and backgrounds (Cohen & Lotan, 2014). The diverse backgrounds and abilities bring about challenges that must be addressed by the teacher to improve student achievement for all. Some examples are English Language Learners (ELLs) who may need support to acquire the language. Language proficiency and mathematics achievement are positively related (e.g., Secada, 1992). Special needs students may have reading difficulties and behavior problems that raise engagement issues and their consequences. Gifted students have to be challenged in order to be kept engaged. As a result, Obara (2010) argues that effective mathematics coaches need to have the skills to address these various needs.

Teachers have different learning styles and backgrounds and therefore require differentiation of help from the coach. Hughes (2015) states the importance of adapting her strategies as a coach in terms of how to help a teacher. She argues that the success of implementation of new strategies depended on the coach's ability to help the teacher visualize practices and the coach's efforts to trim and decompress teaching practices.

1.1.2. Factors within the school and school district

Fig. 1 shows that how coaching is accomplished depends on the school and district (e.g., Mudzimiri et al., 2014; Obara, 2010). The proposed factors within the school and school district are adequate financial and administrative support, the knowledge and skills of district and school leaders in terms of new instructional practices and the implementation process, professional development for school leaders concerning how to bring about an environment that supports coaching, and equitable and thorough guidelines for hiring coaches who can be respected by principals and teachers.

For example, Obara (2010) argues that there must be adequate financial and administrative support for the coaching program. The financial support is required for the salaries of the coaches and funding for their professional development. School administrators must support the coaching program. The coach's relationship with the principal is important in the establishment of an effective coaching program. For example, the principal must create environments for discussion among all parties involved (Poglinco et al., 2003).

Developing the skills and knowledge of the district leaders and school administrators can add to their capacity to spearhead instructional change (Marsh et al., 2005). School and district leaders must know how to develop strong mathematics teachers and be able to obtain resources that continue to support mathematics instruction. When district leaders know the new instructional strategies and how to implement them, it is not difficult to develop the coaching program (Neufeld & Roper, 2003). According to Obara (2010), knowledgeable leaders know that the coach's accessibility matters as teachers require timely feedback to learn how to use the new instructional strategies. In fact, Harbour (2015) found a strong positive relationship between student achievement in mathematics and a full-time mathematics coach. The results were not replicated when part-time coaches were employed.

In terms of the coach's accessibility, the school district leaders can structure the times when teachers meet the coaches (Hopkins, Spillane, Jakopovic, & Heaton, 2013). Bengo (2013) maintains that time is important in a number of ways. It takes time for willing teachers to learn new instructional strategies as these strategies tend to be paradigm shifts. Therefore, coaching is most effective when it happens on a consistent basis and over an extended time period (Hughes, 2015). Ideally, a teacher should work with a coach multiple days per week for many weeks to learn the new strategies (Hughes, 2015). Time is also needed for observations (Piper & Zuilkowski, 2015). It is important that the coach witness issues as they happen versus being told about them (Hughes, 2015). The coach's observations may enable him or her to be better able to determine the challenge(s) the teacher is facing. Coaching should be available as needed since the likelihood of a teacher learning the new methods increases if the teacher continues to be supported through the process (Hughes, 2015).

Principals need professional development as they must know how to create an environment in which teachers know the gains from the coaching program (Obara, 2010). All teachers need to see the value of being helped by someone with their professional growth (e.g., Hansen, 2009).

The mathematics coaching role is a complex one (e.g., Campbell & Malkus, 2011). For instance, coaches must be ready to deal with teachers and administrators who resist change, those who welcome change (Obara, 2010), and some teachers who see coaches as evaluators (Poglinco et al., 2003). Neufeld and Roper (2003) argue that clear guidelines of what is important in the recruiting process will help with the hiring of coaches with these qualities.

1.2. Purpose of the study

I present the results collected in the course of the broader study (Bengo, 2013). The broader study, mathematics coaching to improve teaching practice, used case studies to examine how coaching can be used effectively to improve instruction and student achievement, while exploring teacher emotions during reform initiatives. The findings of the broader study were that mathematics education reforms produced emotional responses such as pride, joy, fear, and a feeling of being drained and ineffective. Coaching could be linked to the emotions that teachers experienced during the reform initiatives. Specifically, teachers experienced positive emotions such as pride and joy because coaching had helped them learn how to use the reform strategies. The other conclusions were that coaching may not help teachers reconstruct their professional self-understanding when it fails to address their self-image issues; and the coaches experienced positive and negative emotions as a result of how well the reforms were being implemented by teachers. The experiences of the coaches suggest a need to support them as they help teachers learn new instructional strategies.

The findings reported here are part of a study affiliated with this broader project. I determine the factors that seem to impact the effectiveness of coaching as a way to improve teaching practices. The research questions are.

- What elements of mathematics coaching help teachers implement new instructional practices?
- What are the implications for the selection of coaches, the training of coaches, and helping teachers?

I employed a case study approach to answer the research questions because it allowed me to perform a detailed study of how coaching can help teachers implement new instructional strategies. The study is therefore explanatory. Case studies are suitable for impact or explanatory studies (Fraenkel & Wallen, 2003). Explanatory studies explain forces causing a situation, circumstances, or plausible causal networks showing an event, situation, or circumstance. I observed coaches working with teachers, observed the teachers they coached in a school, and employed questionnaires, interviews, and archival data to determine the relationship between teachers' use of new instructional strategies and mathematics coaching. The study, therefore, highlights issues associated with the implementation of new instructional strategies.

2. Methodology and methods

2.1. Setting

The study took place in Ontario, Canada. There are various definitions of mathematics coaching employed in Ontario, and math coaches have many titles. In elementary schools "mathematics coaching" is called "coaching for student success." Mathematics coaches can be called elementary math school coaches, secondary math school coaches, numeracy coaches, Ontario Focused Intervention Partnership (OFIP) coaches, or Growing Accessible Interactive Networked Supports (GAINS) coaches. GAINS is a learning strategy for all levels of the system, and the GAINS coaches focus on this strategy.

The coaching program for mathematics teachers can include co-teaching. During co-teaching, the instructional coach can observe teachers during the lesson and provide feedback. Co-teaching involves the coach instructing and giving feedback as well as listening, posing questions, exploring, and probing. Co-planning leads to successful co-teaching. It consists of planning instructional units, cooperative grouping, and roles and responsibilities for co-teachers. The coaches in the study were employed as Instructional Leaders for Grades 7 to 12 by a large and diverse urban Board of Education that served approximately 250,000 students who spoke 110+ languages. The teachers and coaches in the study were part of the Learning Consortium Grade 9 Applied project which was working on the improvement of instructional strategies in Grade 9 applied level mathematics. The instructional support the teachers obtained from the project involved co-planning and co-teaching with board coaches, working with university faculty and collaborating with other Grade 9 applied mathematics teachers and coaches from other boards. The coaches emphasized a partnership approach to coaching and also conducted other math initiatives that involved observing the teachers in the study as Instructional Leaders.

When teachers in the broader study joined the Learning Consortium, coaches also met with teachers to address issues specific to them. As a result, the teachers in the study met with the coaches four times to incorporate more technology in the Grade 9 applied classroom and instructional practice. The nature of this additional support given to the teachers is described in Table 1 by the coaches in the study.

Table 1
The additional instructional support.

Characteristics	To facilitate the integration of existing technology in learning mathematics. The coaching involved is teacher support in planning the lesson within a three-part lesson format and then helping to deliver the lesson and make instructional decisions in the classroom.
Strengths	Successfully integrated technology into three classrooms on a regular basis. Student engagement has increased as evidenced by attendance and participation in class. Teacher collaboration and communication. The team has worked very well together to combine expertise and ideas to create new lessons and structures to support student learning, while having the opportunity to have collegial support in trying new ideas.
Weaknesses	The two major challenges facing this program are bringing other teachers in the school on board and having access to the technology. Department-wide training in the use of the available technology and the purposeful building of lessons and assignments that require the technology.

The coaches had received co-planning and co-teaching training for implementing new instructional strategies from their board. They also received training as a result of their participation in the project from mathematics education faculty and board specialists with expertise in teaching and learning mathematics. They therefore had the training to implement new instructional strategies.

2.2. Participants

I employed purposive sampling in order to talk to the mathematics teachers and coaches involved in the implementation of new instructional strategies. The two coaches were Theresa and Christina. Both were former mathematics teachers and mathematics department heads; Theresa had taught for 16 years and Christina had taught for 17 years. Christina taught in five different schools and had worked for two years as a coach at the time of the study. Theresa taught mathematics in three different schools. She had been a coach for five years at the time of the study. I had collaborated with them before the study in other professional development settings and knew their work.

I also collected data from the following teachers: Robert, Helen, Andrew, and James. Robert had taught for 34 years. He taught the Grade 9 applied mathematics course during the study. Helen taught Grade 9 applied mathematics during the study and was in her sixth year of teaching. Andrew was in his eleventh year of teaching. He taught Grade 9 applied mathematics at the school and at a previous school. James had been a teacher for 25 years and was a former instructional coach. He had taught Grade 9 applied mathematics. James had considerable experience teaching troubled youth, science, and essential, applied, and special education mathematics. The teachers and coaches agreed to participate in the study without any promise of compensation. The teachers had been part of the Learning Consortium project for four years by the time of the study. They were also visited at least once a month by the faculty leading the project.

2.3. Data collection

The various instruments used in the study are described here including details about their administration. I collected data for one year. Observations, surveys, interviews and archival data were combined to determine the components of effective coaching developed so far in the current literature. The types of instruments and combination used in this study are in Table 2 and have been employed in studies on mathematics coaching such as Campbell and Malkus (2010) and Mudzimiri et al. (2014).

The next section describes in more detail the self-assessment survey, Confidence Survey, semi-structured interviews for coaches, critical incident interviews, archival data and observations.

2.3.1. Self-assessment survey

A 20-item survey (McDougall, 2004) was administered once to the coaches at the beginning of the study. The items were part of "a descriptive tool from a research synthesis (Ross, McDougall, & Hogaboam-Gray, 2000) and the National Council of Teachers of Mathematics (NCTM) policy statements (NCTM, 1989, 1991, 2000) that identified 10 dimensions of effective mathematics teaching (standards-based teaching)" (Bruce & Ross, 2008, p. 352). Respondents were asked to agree or disagree using a six-point Likert scale. The reversal of negatively worded items results in a high score on the instructional scale representing high-fidelity implementation of mathematical reforms. Evidence of its validity and reliability has been presented in Ross, McDougall, Hogaboam-Gray, and LeSage (2003).

2.3.2. Confidence survey

The Confidence Survey (Manouchehri, 2003) was administered to all participants once at the beginning of the study. It consisted of two parts. In the first part, participants were asked to use a rating scale to indicate the level of difficulty they encountered (1 = easy) implementing various components of mathematics reform; for

Table 2
Instruments by purpose and number of participants.

Self-assessment survey	
Purpose	The survey assessed beliefs and self-reported practices for teaching and learning. The data provided information on whether the participants viewed the mathematics standards as consistent with their own instructional goals and applicable to their setting.
Participants	All Grade 9 applied math teachers and math coaches.
Confidence survey	
Purpose	Respondents were asked to assess their confidence with new instructional roles and techniques recommended for their practice.
Participants	All Grade 9 applied math teachers and math coaches.
Semi-structured interviews for teachers	
Purpose	The interviews were conducted in order to assess the nature of teacher learning and to provide information related to their educational background, teaching experience, courses they taught, and the quality and quantity of professional development they obtained.
Participants	The Grade 9 applied math teachers from the school in the case study.
Semi-structured interviews for coaches	
Purpose	These determined the nature of the coaching program in the school.
Participants	The coach or coaches involved with the school.
Critical incident interviews	
Purpose	The interviews were used to obtain coach accounts of the components of effective coaching.
Participants	All Grade 9 applied math teachers in the school and math coaches.
Archival data	
Purpose	The data was used to know the aspects of the coaching initiative and collected from individuals in the school; for example, the office staff and the school's administrators.
Purpose	The guide assessed how the teacher implemented the new methods.
Participants	Grade 9 applied math teachers

example, teaching skills for problem solving, conceptual understanding, and making connections, as well as using inquiry-based instruction and technology. The second part asked participants to indicate the level of assistance they would need to implement the new instructional practices.

2.3.3. Semi-structured interviews for coaches

The semi-structured interviews were conducted with coaches once at the beginning of the study. The interview questions focused on the coaching program, the challenges of the program, what the coaching did for teachers, and what coaches gained from their participation. They were based on a survey by Grossek (2008), who used similar research questions. Due to the difficult time schedules involving the two coaches, interviews were conducted online or coaches responded to open-ended surveys. This method has benefits (Markham & Bayn, 2008). For instance, respondents answer questions in writing after considering them in depth.

2.3.4. Critical incident interviews

The interviews were conducted at the beginning of the study and repeated for clarification during the study. Seventeen critical incidents were obtained as a result. I used them to enhance the case studies. These interviews require respondents to identify events or experiences that are critical for some purpose (Kain, 2004). The study is also an "interactive venture." As a researcher, I wanted to speak to people whose experiences were relevant to my questions. Observations or surveys alone would be inadequate as I wanted to determine how coaches viewed their experiences. Kain (2004) used the critical incident technique for the same reasons. The incidents from the critical interviews were combined for analysis, and generalizations about the event or activity were made from the commonalities of the incidents (Kain, 2004). "Data collection continues until enough critical incidents have been gathered so that in the analysis of these incidents no new critical behaviors (categories) appear" (Kain, 2004, p. 75). I gathered critical incidents that way. I asked participants for clarification and asked more questions to improve the reliability and validity of the interviews. The coaches were asked the following questions during the critical incident interviews:

- Think of a time when you were effective at helping a teacher(s) use new instructional strategies in a Grade 9 applied mathematics classroom. (Pause). Tell me what you did that made them effective? (Positive Version)
- Think of a time when you were unable to help a teacher(s) use new instructional strategies effectively in a Grade 9 applied mathematics classroom. (Pause). Why were you unsuccessful? (Negative Version)

2.3.5. Archival data

Twenty-six documents were collected over the duration of the study. The documents collected included the vision statement of the school, email correspondence between teachers and researcher, correspondence between participating teachers and project leaders, and meeting minutes or agendas (staff, committee, heads, etc.). I also gathered policies regarding the use of the new strategies in the school as mentioned in the Department of Mathematics policy documents, Learning Consortium handouts and materials given to participants, curriculum documents, course materials, school websites, the Learning Consortium Grade 9 Applied Project website, and other school documents on coaching initiatives in the school.

2.3.6. Observations

I observed the coaches at a full-day Learning Consortium session as they worked with teachers. I also observed the teachers they had worked with in a particular school weekly for a semester. I used the classroom observation guide McDougall (2004) employed in a study on coaching and teacher learning, which contains guidelines for observing teaching practices and recording field notes. Classroom observations determined how coaching helped teachers adopt new instructional practices. Fraenkel and Wallen (2003) argue that sustained observation can be employed to obtain a more accurate account of how participants work. Observations were audiotaped to provide a permanent record of events to compare with field notes. I observed teachers as participant-as-observer, taking part in the activities completely and ensuring that those I was observing knew that I was conducting research as well.

The archival data, critical incident interviews, semi-structured interviews with the coaches, and survey responses were collected as teacher observations were taking place. This allowed me to collect data while coding to make ongoing validation checks on the coaches. By constantly interacting with participants and asking questions about data, I was able to develop case studies based on their experiences.

2.4. Data analysis and interpretation

The interview questions were transcribed and imported into NVivo 9, a data software program for inductive analysis with observations. A general classification system was created for the critical incident interviews in order for subsequent coding to be inductive. Inductive analysis includes "scanning the data for categories of phenomena and for relationships among such categories, developing working typologies and hypotheses on an examination of initial cases and then modifying and refining them on the basis of subsequent cases" (LeCompte, Preissle, & Tesch, 1993, p. 254). Interviews and observations were combined with ongoing analysis to develop an understanding of the process of teacher learning with coaching. The research questions guided the data analysis: What elements of coaching help teachers implement new instructional practices? What are the implications for selecting coaches, training coaches, and helping teachers?

Before the coding process, all field notes and transcriptions were transferred into the NVivo 9 program. I created 23 primary documents. With the primary documents created, I started the coding process. The original code lists were generated from the research questions, archival data, critical incident interviews, participant perceptions of their practice, and my classroom observations, which resulted in 54 codes. Each primary document was then reviewed line by line and coded. Sometimes annotations or quotations were added during the process. As coding proceeded, more themes and patterns emerged from the data and more codes were developed. I employed the query tool to analyze data. As I coded, recoded, or uncoded data, the final list of codes expanded to 84. I analyzed the data, reviewing portions that were connected to a particular theme. This allowed me to understand why certain things happened. I used the query tool to conduct within-case analyses. I was then able to determine the components of effective coaching classify and cross-reference the findings with observation data and interview data. By combining the data, triangulation of perspectives and cases was obtained. Through analyzing mathematics beliefs, teaching practices, and critical incidents, I was able to determine the components of effective coaching.

My approach to data analysis and collection is based on Fraenkel and Wallen's (2003) observation about validity. Fraenkel and

Wallen (2003) note: “Validity, therefore, depends on the amount and type of evidence there is to support the interpretations researchers wish to make concerning data they have collected” (p. 159). In qualitative studies, much depends on the perspectives of the researcher. As a result, a number of techniques were used to check the researchers' perceptions for accuracy. During the study, I kept extensive records, including all audiotaped interviews and transcriptions; various emails; an audit trail showing when the data was collected; and researcher field notes in the form of summaries of collected data, analyses, and theoretical notes. The documents make the study credible and confirm that it took place. Members' checks were conducted. Therefore, each participant was allowed to react to my interpretation to ensure accuracy. This kind of participant involvement adds to the validity of the study (Fraenkel & Wallen, 2003). I triangulated the data over time, over data sources (surveys, interviews, observations, and archival data), and between participants. I thus developed validity by using multiple instruments and by the way I made sense of the evidence that I gathered.

3. Results and discussion

3.1. The components of effective mathematics coaching

The results show that the coach needs to convince some teachers that new instructional strategies work. From the coaches' interview responses, the inability to convince teachers those strategies could work was the underlying cause of the failure to implement them. Convincing teachers that the strategies could work was influenced in part by whether the coach was teaching at the time she advised the teachers. Christina specifically mentioned having her beliefs about the students' capabilities and the ways they learn challenged and dismissed because she was not in the classroom any more due to her role as coach. This finding suggests that the credentials of the coach are important, contrary to what Scott, Cortina, and Carlisle (2012) state about a literacy coach's credentials. In that setting, the coach's formal credentials and teaching background were not as important as what the coach did with teachers. Their study differs from the current one in terms of design, number of participants and subject area. These differences could explain the inconsistency. The finding, however, is consistent with effective coaching research, since whether the coach is credible to teachers and can be respected are components of effective coaching (e.g., Obara, 2010). Coaches in Ontario could be out of classes for at least five years, as in Theresa's case. The findings underscore the need for more research on the types of credentials that impact a coach's effectiveness.

The coach's knowledge of content matter has been noted as an element of effective coaching in section 1.1. Christina observed that the teachers she was working with were mathematicians at heart. This meant to her that she had to prove herself a mathematician first and then a teacher in order to work with them. In contrast to the findings in section 1.1, this indicates that content knowledge is necessary in planning of lessons and as a way to earn credibility and therefore trust. The results suggest that secondary mathematics teachers may only be engaged in coaching if coaches can prove their subject matter expertise. This is inconsistent with Knight et al. (2015) who argue that the implementation of a coaching cycle may be the most important thing that coaches do. Their results however are based on large samples compared to the current study. They also focus on instructional coaching. These differences could explain the inconsistency. The results also show that trust was an important element of effective coaching. Christina did mention the importance of trust a few times in her interviews. This finding is consistent with Psencik (2015).

The results show that effective mathematics coaching requires that the math coaches are able to differentiate the help they provide to teachers. Based on the classroom observations, interviews with coaches, discussions with teachers and the archival data, coaching did not have the desired impact when it failed to address the individual issues of teachers. The findings are therefore consistent with the research in section 1.1. All teachers reported benefiting from the coaching experience. For example, Robert explained that the support was important because “teachers needed to be shown that these methods actually worked” (October, 2011). Helen mentioned that the sessions and the materials were very useful because student achievement improved. James and Andrew reported smaller gains from coaching in interviews. Specifically, they found it useful discussing classroom issues with other math teachers.

The data, however, showed that all teachers made decisions based on their knowledge, goals, and beliefs. Teachers made decisions about what materials to use, how to adapt them and what instructional strategies to use regularly. For example, I observed that Robert used technology most of the time and incorporated many inquiry activities and group work in lessons, while Helen emphasized literacy, paid more attention to how students performed algorithms, classroom order, notebook organization, and giving feedback. Neither had employed the evaluation and assessment practices of the new instructional strategies as they were supposed to. Andrew's interviews show to some extent that the coaches did not address the issues he had with the new methods. He thought that he may have found the new methods ineffective because he did not use them long enough or modify them. It is therefore possible that the coaches could have had an impact on Andrew's beliefs if they had examined some of his misconceptions. The latter finding also suggests that effective coaching should be continual, as learning takes time. This conclusion is also consistent with the research in Section 1.1.

An effective coaching program has the necessary resources readily available. Christina indicated that she was unable to improve the teaching strategies for the Grade 9 applied math program because she “could not demonstrate the effectiveness of teaching through problem solving in a workshop setting – teachers needed to ‘see’ this teaching strategy with the students” (critical incident interview). I also found that the resources deemed suitable by Learning Consortium personnel were problematic for Helen. Helen picked the parts of the resources that did not require considerable thinking or literacy skills so that her students could easily understand them.

Based on archival and interview data, in-school factors such as the support of the administration did not help teachers implement new instructional strategies. The four teachers in the study worked in a school where the Department of Mathematics and the administration of the school supported them as they learned the new methods. For example, the administration supported them in terms of days off to participate in the Learning Consortium activities and provided technology to support the new instructional practices. I observed these instructional practices had an impact on how James and Andrew saw themselves as teachers and affected how they knew how to help their students. For example, James's coaching role had been reduced with the introduction of the new instructional strategies and Andrew had to implement strategies that he did not think were effective for students. He complained about not being allowed to adapt them as he wanted. Their experiences can be linked to their need for control, experience, and education. Their experiences suggest that effective mathematics coaching must address the instructional issues that all teachers have.

The results show that job-embedded learning was needed to demonstrate how the teaching strategies worked. Christina mentioned this a few times in the interview data as one of her frustrations. This finding is consistent with Richard (2003). That the coach tried problem solving in a workshop setting known not to be an effective way of helping adults learn emphasizes in part the importance of training coaches, as many have noted (e.g., Knight et al., 2015). The impact of job-embedded learning seemed to be effective with Christina's teachers based on the "aha" moments she observed with many skeptical teachers. This finding is consistent with Campbell and Malkus (2014), for example, who argue that coaching will help teachers learn new instructional strategies. Theresa, on the other hand, could not convince her teachers with evidence that problem solving could be used with students struggling in mathematics. This suggests the need to differentiate the help given to teachers.

Both coaches mention that time was important in the implementation of new instructional strategies. Time was required to establish rapport with teachers, as Knight (2006) has noted. Theresa suggested that time is required to do the much-needed work of changing teacher beliefs about effective practices.

Christina mentioned in her surveys that she implemented new strategies as a teacher because she understood them easily through training, could incorporate them into current practices, could discuss them with peers easily, and found the strategies did not require a lot of preparation to be used. She would also implement new strategies as a teacher if they served her students well; for example, if the strategies prepared her students for the workplace or they helped at-risk students or students in essential-level courses. The teachers in the study also decided whether or not to implement the new strategies for these reasons based on observation and interview data. These findings are consistent with the components of effective mathematics coaching research in Section 1.1, as the mathematics coach is employed to improve teacher understanding of new instructional strategies so that they are easy to use and to provide the necessary support for their inclusion into practice.

3.2. Implications for helping teachers, the selection of coaches and the training of coaches

This section provides the implications in categories.

3.2.1. Helping teachers

The teachers got considerable instructional support to show the learning that I observed. This finding suggests that coaching initiatives are better designed long-term and frequent. Teachers in the study had issues with the resources from the coaching initiative. This is a common challenge (Bengo, 2013). What does the resources problem really represent? How can it be resolved? The resources are after all developed to improve student achievement.

Based on the results, favorable in-school factors may not have the intended impact if coaching has not addressed the individual issues of teachers. This finding suggests that coaching must be differentiated to address the individual issues and the coaching initiatives must be seen as system efforts. For example, school factors such as the support of administrators will have a positive impact on teachers being coached if the coaching initiative has also addressed the individual teacher implementation issues.

3.2.2. Selection of coaches

Christina mentioned that she was happy that they had the courage to try job-embedded learning for the first time in secondary schools. Since coaching is about helping teachers use new instructional strategies, a coach's courage to try new things with teachers or initiatives that are likely to be met with resistance is an important component of effective coaching. This shows the high expectations in terms of the training required to prepare coaches for these roles as well as their recruitment. Courage is defined as a quality of mind or spirit. Given that it is a characteristic, it is not easy to cultivate. This suggests further that recruitment of coaches should include an assessment of courage.

3.2.3. Training of coaches

Efforts are required to keep coaches current. This is not an easy task as they have many responsibilities. A coach needs to respond to issues that can impact learning over time and cannot be predicted perfectly, as mentioned above. Coaches said that collaboration with teachers helped them learn as well. Given its importance to them it may be a worthwhile component of their training as Campbell and Malkus (2014) have noted. Part of the professional development for coaches would include field lessons such as these with some supervision from the training staff.

Since all the teachers in the study made decisions based on their knowledge, goals and beliefs, coaches need training on how to address issues in these areas effectively. But the data presented above also shows that all the teachers in the study made decisions to help their students. This might be a way to introduce new instructional strategies. The coaches could provide evidence of how the new methods benefit students in ways all teachers can relate to. In the process, coaches can also address problematic beliefs (beliefs inconsistent with the implementation of the new methods) and their causes as well as acknowledge the beliefs that inspire change before implementing the coaching initiatives. This may be the way to launch coaching initiatives that are likely to be successful.

The study is exploratory in nature; thus, its findings can only be used toward a better understanding of the factors that need to be addressed when implementing new instructional strategies with a mathematics coach. Another limitation of the study is its external validity or generalizability based on the number of participants.

References

Barlow, A. T., Burroughs, E. A., Harmon, S. E., Sutton, J. T., & Yopp, D. A. (2014). Assessing views of coaching via a video-based tool. *ZDM: International Journal on Mathematics Education, 46*, 227–238.

Bengo, P. (2013). *Mathematics Coaching to Improve Teaching Practice: The Experiences of Mathematics Teachers and Coaches* (Doctoral dissertation). University of Toronto.

Blank, R. F. (2013). What research tells us: Common characteristics of professional learning that leads to student achievement. *Journal of Staff Development, 34*(1), 51–52.

Black, P., & William, D. (1998). Assessment and classroom learning. *Assessment in Education: Principles, Policy and Practice, 5*(1), 7–74.

Bruce, C. D., & Ross, J. A. (2008). A model for increasing reform implementation and teacher efficacy: Teacher peer coaching in grade 3 and 6 mathematics. *Canadian Journal of Education, 31*(2), 346–370.

Campbell, P. F., & Malkus, N. N. (2010). The impact of elementary mathematics specialists. *The Journal of Mathematics and Science: Collaborative Explorations, 12*, 1–28.

Campbell, P. F., & Malkus, N. N. (2011). The impact of elementary mathematics coaches on student achievement. *The Elementary School Journal, 111*(3), 430–454.

Campbell, P. F., & Malkus, N. N. (2014). The mathematical knowledge and beliefs of elementary mathematics specialist-coaches. *ZDM: International Journal on Mathematics Education, 46*(2), 213-225.

Cataldo, P. (2013). From classroom to coach: One teacher's journey. *Teaching Children Mathematics, 20*(2), 110–115.

Chval, K. B., Arbaugh, F., Lannin, J. K., van Garderen, D., Cummings, L., Estapa, A. T., et al. (2010). The transition from experienced teacher to mathematics coach: Establishing a new identity. *The Elementary School Journal, 111*(1), 191–216.

Cohen, E. G., & Lotan, R. A (2014). *Designing group work: Strategies for the heterogeneous classroom* (3rd ed.). New York, NY: Teachers College Press.

Cornett, J., & Knight, J. (2008). Research on coaching. In J. Knight (Ed.), *Coaching: Approaches and perspectives* (pp. 192–216). Thousand Oaks, CA: Corwin Press.

Costa, A. L., & Garmston, R. J. (2002). *Cognitive coaching: A foundation for renaissance schools* (2nd ed.). Norwood, MA: Christopher-Gordon.

Fraenkel, J. R., & Wallen, N. E. (2003). *How to design and evaluate research in education* (5th ed.). New York, NY: McGraw-Hill.

Grossek, H. (2008). *To what extent does coaching contribute to the professional development of teachers?* Research project completed under the auspices of the DEECD School Research Grants Proposal.
Hansen, P. (2009). *Mathematics coaching handbook: Working with teachers to improve instruction*. Larchmont, NY: Eye on Education.
Harbour, K. (2015). *A multi-level analysis using NAEP data: Examining the relationships among mathematics coaches and specialists, student achievement, and disability status* (Doctoral dissertation). Retrieved from University of Louisville Electronic Theses and Dissertations. Paper 2088 http://dx.doi.org/10.18297/etd/2088.
Hindman, A. H., & Wasik, B. A. (2012). Unpacking an effective language and literacy coaching intervention in head start : Following teachers' learning over two years of training. *The Elementary School Journal, 113*(1), 131–154.
Hopkins, M., Spillane, J. P., Jakopovic, P., & Heaton, R. M. (2013). Infrastructure redesign and instructional reform in mathematics: Formal structure and teacher leadership. *The Elementary School Journal, 114*(2), 200–224.
Horwitz, J., Bradley, J., & Hoy, L. (2011). Identity crisis: External coaches struggle to clarify roles and maintain focus on student learning. *Journal of Staff Development, 32*(1), 30–32, 38.
Hughes, K. A. (2015). *Exploring influences of mathematics coach-teacher interactions on the development of teacher pedagogical knowledge, effective mathematical teaching practices, and a classroom culture of mathematical inquiry* (Doctoral dissertation). US: Ohio University. Retrieved from electronic theses and dissertations @ Ohio University.
Hull, T. H., Balka, D. S., & Miles, R. H. (Eds.). (2009). *A guide to mathematics coaching: Processes for increasing student achievement*. Thousand Oaks, CA: Corwin Press.
Kain, D. L. (2004). Owning significance: The critical incident technique in research. In K. B. deMarrais, & S. D. Lapan (Eds.), *Foundations for research: Methods of inquiry in education and the social sciences* (pp. 69–85). Mahwah, NJ: Lawrence Erlbaum Associates.
Kilpatrick, J., Swafford, J., & Findell, B. (Eds.). (2001). *Adding it up: Helping children learn mathematics*. Washington, DC: Mathematics Learning Study Committee, Center for Education, Division of Behavioral and Social Sciences and Education, National Academy Press.
Knight, J. (2006). Instructional coaching. *School Administrator, 63*(4), 36–40.
Knight, J. (2007). *Instructional coaching: A partnership approach to improving instruction*. Thousand Oaks, CA: Corwin Press.
Knight, J., Elford, M., Hock, M., Dunekack, D., Bradley, B., Reshler, D. D., et al. (2015). 3 steps to great coaching: A simple but powerful instructional coaching cycle nets results. *Journal of Staff Development, 36*(1), 10–12, 14, 16, 18.
Kuijpers, J. M., Houtveen, A. A. M., & Wubbels, T. (2010). An integrated professional development model for effective teaching. *Teaching and Teacher Education, 26*, 1687–1694.
LeCompte, M. D., Preissle, J., & Tesch, R. (1993). *Ethnography and qualitative design in educational research* (2nd ed.). San Diego: Academic Press.
Leinhardt, G., & Greeno, J. G. (1986). The cognitive skill of teaching. *Journal of Educational Psychology, 78*, 75–95.
Manouchehri, A. (2003). Factors facilitating mathematics reform efforts: Listening to the teachers' perspectives. *Action in Teacher Education, 25*(3), 78–90.
Markham, A. N., & Bayn, N. K. (Eds.). (2008). *Internet inquiry: Conversations about method*. Thousand Oaks, CA: Sage.
Marsh, J. A., Kerr, K. A., Ikemoto, G. S., Darilek, H., Suttorp, M., Zimmer, R. W., et al. (2005). *The role of districts in fostering instructional improvement: Lessons from three urban districts partnered with the Institute for Learning*. Santa Monica, CA: Rand Corporation.
McDougall, D. (2004). *PRIME school mathematics improvement: Leadership Handbook*. Toronto, ON: Thomson, Nelson.
Mudzimiri, R., Burroughs, E. A., Luebeck, J., Sutton, J., & Yopp, D. (2014). A look inside mathematics coaching: Roles, content and dynamics. *Education Policy Analysis Archives, 22*(53), 1–32.
National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: Author.
National Council of Teachers of Mathematics. (1991). *Professional standards for teaching mathematics*. Reston, VA: Author.
National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: Author.
Neufeld, B., & Roper, D. (2003). *Coaching: A strategy for developing instructional capacity – promises and practicalities*. Washington, DC: Aspen Institute Program on Education and Annenberg Institute for School Reform.
Obara, S. (2010). Mathematics coaching: A new kind of professional development. *Teacher Development, 14*(2), 241–251.
Piper, B., & Zuilkowski, S. S. (2015). Teacher coaching in Kenya: Examining instructional support in public and nonformal schools. *Teaching and Teacher Education, 47*, 173–183.
Poglinco, S. M., Bach, A. J., Hovde, K., Rosenblum, S., Saunders, M., & Supovitz, J. A. (2003). *The heart of the matter: The coaching model in America's choice schools*. Philadelphia, PA: Consortium for Policy and Research in Education, University of Pennsylvania.
Psencik, K. (2015). The character of a coach: Success depends on trustworthiness. *Journal of Staff Development, 36*(1), 52–57.
Richard, A. (2003). *Making our own road: The emergence of school-based staff developers in America's public schools*. New York, NY: Edna McConnell Clark Foundation.
Ross, J. A., McDougall, D. E, & Hogaboam-Gray, A. (2000). *Elementary school reform and higher order reasoning in mathematics*. Peterborough, ON: OISE/UT Trent Valley Centre.
Ross, J. A., McDougall, D., Hogaboam-Gray, A., & LeSage, A. (2003). A survey measuring elementary teachers' implementation of standards-based mathematics teaching. *Journal for Research in Mathematics Education, 34*(4), 344–363.
Scott, S. E., Cortina, K. S., & Carlisle, J. F. (2012). Understanding coach-based professional development in "Reading First": How do coaches spend their time and how do teachers perceive coaches' work? *Literacy Research and Instruction, 51*(1), 68–85.
Secada, W. G. (1992). Race, ethnicity, social class, language and achievement in mathematics. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 623–660). New York, NY: Macmillan.
Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1–22.
Smith, M. S. (1995). One teacher's struggle to balance students' needs for challenge and success. In *Paper presented at the annual meeting of the north american chapter of the international group for the psychology of mathematics education, October 21–24, Columbus, OH*.
Teemant, A. (2014). A mixed-methods investigation of instructional coaching for teachers of diverse learners. *Urban Education, 49*(5), 574–604.
West, L., & Staub, F. (2003). *Content-focused coaching: Transforming mathematics lessons*. Portsmouth, NH: Heinemann.