The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

by

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Abstract

Certified teachers in British Columbia (BC) schools can be assigned to teach secondary mathematics without having a major, minor, or formal background in mathematics. This is known as out-of-field teaching. These non-mathematics subject specialist teachers (NMSSTs) must learn or relearn the subject matter of mathematics to teach secondary mathematics. This study investigates what professional learning activities NMSSTs participate in to gain subject matter content knowledge in mathematics, which activities these teachers believed best facilitated the acquisition of subject matter, and which they believed helped them to teach secondary mathematics better. This was a descriptive study using survey methods. Sixteen professional learning activities were considered. The survey questionnaire was distributed and completed online. Sixty-two NMSSTs completed the survey in full. Most learned the subject matter autodidactically from teaching secondary mathematics, referring to textbooks, or going online. However, formal learning activities such as completing a graduate degree in mathematics or a mathematics-related field best facilitated the acquisition of the subject matter and helped in teaching mathematics better. Other findings include the following: learning from an expert in the field was highly valued; professional learning days were not highly valued but frequently participated-in; the perceived level of subject matter content knowledge of those who completed a graduate degree and those who did not were the same; the NMSST characteristic of perceived level of subject matter content knowledge did not influence participants in this study to self-identify as mathematics subject specialists. Recommendations for practitioners included not learning the subject matter in isolation and to find a mentor. Recommendations for school leaders were to redesign professional development days and to consider purposeful teaching assignments. Recommendations for future research were to develop a self-assessment tool and to implement a study on subject matter acquisition of NMSSTs in a master of mathematics education program. Recommendations for policy-makers included providing alternative professional development opportunities for teachers and setting standards for NMSSTs to help them self-assess their subject matter content knowledge in mathematics.

Keywords: content knowledge; out-of-field teaching; professional learning; experiential learning; self-directed learning; subject matter
Dedication

• To my mom, dad, husband, and daughter:
  I could not have done this without you.

• To my brother, my sister, and the Jing Ye Fund:
  My family is integral to my success.

• To my students, colleagues, and friends:
  I love and appreciate your support, encouragement, and inspiration.

  I did not expect to be here—and here I am!

  Thank you all!
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# Table of Contents

Approval ...................................................................................................................... ii
Ethics Statement ........................................................................................................ iii
Abstract ..................................................................................................................... iv
Dedication .................................................................................................................... v
Acknowledgements ..................................................................................................... vi
Table of Contents ....................................................................................................... vii
List of Tables ............................................................................................................... x
List of Figures ........................................................................................................... xi
List of Acronyms ......................................................................................................... xii
Glossary ...................................................................................................................... xiii

## Chapter 1. Background to the Study ................................................................. 1
1.1. Introduction ....................................................................................................... 1
1.2. Statement of the Problem .............................................................................. 6
1.3. Purpose of the Study ..................................................................................... 7
1.4. Research Question ....................................................................................... 8
1.5. Significance of the Study ............................................................................ 8
1.6. Delimitations .................................................................................................. 10
1.7. Limitations ...................................................................................................... 11
1.8. Organization of the Study ........................................................................... 11

## Chapter 2. Literature Review ........................................................................ 13
2.1. Learning Subject Matter ............................................................................. 13
   2.1.1. System change .................................................................................... 15
   2.1.2. Profound understanding .................................................................. 17
   2.1.3. Higher education ............................................................................ 19
2.2. Teachers as Learners ................................................................................... 21
   2.2.1. Experiential learning ........................................................................ 21
   2.2.2. Teaching expertise .......................................................................... 23
   2.2.3. Expertise versus experience ............................................................ 25
2.3. Stages of Self-Directed Learning .................................................................. 27
   2.3.1. Stage 1: Dependent learners ............................................................ 28
   2.3.2. Stage 2: Moderately self-directed learners ..................................... 28
   2.3.3. Stage 3: Intermediate self-directed learners ................................... 29
   2.3.4. Stage 4: Self-directed learners ....................................................... 31
2.4. Conceptual Framework ............................................................................... 32
2.5. Summary ........................................................................................................ 33

## Chapter 3. Design of the Study ...................................................................... 36
3.1. Research Design ............................................................................................ 36
3.2. Setting ............................................................................................................ 37
3.3. Population Sample ....................................................................................... 39
   3.3.1. Sample size ...................................................................................... 40
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3.2.</td>
<td>Sampling methods</td>
<td>40</td>
</tr>
<tr>
<td>3.4.</td>
<td>Instrumentation</td>
<td>43</td>
</tr>
<tr>
<td>3.5.</td>
<td>Pilot Test</td>
<td>44</td>
</tr>
<tr>
<td>3.6.</td>
<td>Reliability and Validity</td>
<td>46</td>
</tr>
<tr>
<td>3.7.</td>
<td>Data Analysis Plan</td>
<td>47</td>
</tr>
<tr>
<td>3.8.</td>
<td>Potential Benefits</td>
<td>50</td>
</tr>
<tr>
<td>3.9.</td>
<td>Potential Risks</td>
<td>50</td>
</tr>
<tr>
<td>3.10.</td>
<td>Confidentiality</td>
<td>50</td>
</tr>
<tr>
<td>3.11.</td>
<td>Retention and Destruction of Data</td>
<td>51</td>
</tr>
<tr>
<td>3.12.</td>
<td>Dissemination of Results</td>
<td>51</td>
</tr>
<tr>
<td>3.13.</td>
<td>Summary</td>
<td>51</td>
</tr>
</tbody>
</table>

**Chapter 4. Data Analysis**

<table>
<thead>
<tr>
<th>Subsection</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1.</td>
<td>Univariate Analysis</td>
<td>54</td>
</tr>
<tr>
<td>4.1.1.</td>
<td>The participant profile</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>Age group</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>Years of experience</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>BC schools</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>Self-identification</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>Teaching assignment</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>Teaching expertise</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td>Subject matter content knowledge</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>Summary Characteristics</td>
<td>61</td>
</tr>
<tr>
<td>4.1.2.</td>
<td>Professional learning activities</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td>Frequency and type of participation</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>Most valuable learning activity</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>Comparing most valuable learning activities</td>
<td>69</td>
</tr>
<tr>
<td>4.1.3.</td>
<td>Acquisition of subject matter and improved teaching</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td>Learning from teaching</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td>Master degree completion</td>
<td>75</td>
</tr>
<tr>
<td>4.1.4.</td>
<td>Other professional learning activities</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td>Autodidactic learning activities</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td>Learning communities as professional learning</td>
<td>77</td>
</tr>
<tr>
<td></td>
<td>Traditional professional development</td>
<td>77</td>
</tr>
<tr>
<td></td>
<td>Formal learning activities</td>
<td>77</td>
</tr>
<tr>
<td></td>
<td>Final comments</td>
<td>77</td>
</tr>
<tr>
<td>4.2.</td>
<td>Bivariate Analysis</td>
<td>78</td>
</tr>
<tr>
<td>4.2.1.</td>
<td>Years of experience and teaching assignment</td>
<td>78</td>
</tr>
<tr>
<td>4.2.2.</td>
<td>Self-identifying as mathematics subject specialist teachers</td>
<td>80</td>
</tr>
<tr>
<td>4.2.3.</td>
<td>Facilitating acquisition and teaching mathematics better</td>
<td>81</td>
</tr>
<tr>
<td>4.2.4.</td>
<td>Teaching expertise and subject matter content knowledge</td>
<td>83</td>
</tr>
<tr>
<td>4.2.5.</td>
<td>Relationships between NMSST characteristics</td>
<td>85</td>
</tr>
<tr>
<td>4.3.</td>
<td>Summary</td>
<td>88</td>
</tr>
</tbody>
</table>

**Chapter 5. Discussion**

<table>
<thead>
<tr>
<th>Subsection</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1.</td>
<td>Relationship to the Literature</td>
<td>92</td>
</tr>
<tr>
<td>5.1.1.</td>
<td>Common themes</td>
<td>93</td>
</tr>
</tbody>
</table>
Learning from experience ................................................................. 93
Learning from an expert ................................................................. 96
Building expertise ................................................................. 98
Professional development ......................................................... 100

5.1.2. Unexpected findings ....................................................... 101
Self-identification ................................................................. 102
Self-assessment ................................................................. 103
Learning in isolation ............................................................... 106

5.2. Answering the Research Question ...................................... 109
5.2.1. Answering Sub-question 1 ............................................... 110
5.2.2. Answering Sub-question 2 ............................................... 111

5.3. Summary ........................................................................ 111

Chapter 6. Conclusions ................................................................. 115
6.1. Implications ........................................................................ 119
6.1.1. For practitioners .......................................................... 119
6.1.2. For school leadership ..................................................... 121
6.1.3. For future research ....................................................... 123
6.1.4. For policy-makers ........................................................... 125
6.2. Summary ........................................................................ 127

References ............................................................................... 130
Appendix A. Letter to Participate in the Study ................................ 137
Appendix B. Letter to Participate in Pilot Test 1 .......................... 138
Appendix C. Pilot Test Feedback Form ........................................ 140
Appendix D. Letter to Participate in Pilot Test 2 .......................... 142
Appendix E. Certificate of Completion of Research Involving Humans Course on Research Ethics ........................................... 144
Appendix F. Survey Instrument .................................................. 145
List of Tables

Table 4.1. BC Schools Where NMSSTs Taught Secondary Mathematics............ 57
Table 4.2. Frequency of Participation for Each Professional Learning Activity ...... 65
Table 4.3. Types of Online Resources Used by the NMSST Respondents .......... 66
Table 4.4. Most valuable professional learning activity using weighted score ...... 67
Table 4.5. Percent of Participants Ranking the Top 3 Most Valuable Learning Activities .................................................. 68
Table 4.6. Weighted Score of Master or Doctorate Degree Sub-cohort............. 69
Table 4.7. Weighted Score of Mentor or Colleague Sub-cohort..................... 70
Table 4.8. Facilitating the Acquisition of Subject Matter Content Knowledge (SQ1)........................................................................................................ 72
Table 4.9. Helping NMSSTs to Teach Secondary Mathematics Better (SQ2).... 73
Table 4.10. Comparing NMSSTs with and without a Master or Doctorate Degree................................................................................................. 76
Table 4.11. Frequency Distribution of Teaching Experience versus Assignment (Observed Values) (N = 62) ......................................................... 79
Table 4.12. Expected Values for Teaching Expertise and Assignment (N = 62) .... 80
Table 4.13. Chi-Square Test of Self-Identification and NMSST Characteristics .... 81
Table 4.14. Spearman’s Ranked Correlation Coefficients between Strengthening Mathematics Content Knowledge (SQ1) and Becoming a Better Mathematics Teacher (SQ2) ........................................... 82
Table 4.15. Spearman’s Ranked Correlation Coefficients of Perceived Levels of Expertise and Subject Matter Content Knowledge with Sub-questions 1 and 2 .................................................................................. 84
Table 4.16. Spearman’s Ranked Correlation Coefficients of NMSST Characteristics ................................................................................................. 86
List of Figures


Figure 2.1. Types of professional learning activities .................................................. 33

Figure 4.1. Age group of NMSSTs (N = 62). ................................................................. 55

Figure 4.2. Years of experience teaching secondary mathematics (N = 62).............. 56

Figure 4.3. Secondary mathematics teaching assignment of NMSSTs (N = 62). ............................................................ 58

Figure 4.4. Perceived level of expertise as mathematics teachers (N = 62). .......... 59

Figure 4.5. Perceived level of subject matter content knowledge (N = 62). ........... 60

Figure 4.6. Importance of professional learning to strengthen subject matter content knowledge in mathematics for NMSSTs (N = 62). ...................... 61

Figure 4.7. Frequency of participation of types of professional learning (N = 62). Does not include the frequency of “Other” responses. Some “Other” responses were repeated or type was mis-categorized, which would lead to a double count or miscount of participation. “Other” responses were summarized separately in Section 4.1.4........... 64

Figure 4.8. Professional learning activities used with Teaching Secondary Mathematics in percentages (n = 60). .......................................................... 74

Figure 4.9. Inter-related NMSST characteristics. ......................................................... 87
List of Acronyms

BC   British Columbia
BCAMT British Columbia Association of Mathematics Teachers
BCCT British Columbia College of Teachers
CMEC Council of Ministers of Education, Canada
IP   internet protocol
IQR  interquartile range
K-12 Kindergarten to Grade 12
K-7  Kindergarten to Grade 7
NCTM National Council of Teachers of Mathematics
NMSST non-mathematics subject specialist teacher
PDF  portable document format
PLC  professional learning community
PLN  professional learning network
PUFM profound understanding of foundational mathematics
SAIP School Achievement Indicators Program
SFU  Simon Fraser University
SMCK subject matter content knowledge
SQ1  Sub-question 1 (believed best facilitated the acquisition of subject matter)
SQ2  Sub-question 2 (believed helped them to teach mathematics better)
TQS  Teacher Qualification Service
UBC  University of British Columbia
UFV  University of the Fraser Valley
UNBC University of Northern British Columbia
US   United States
UVic University of Victoria
## Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>British Columbia Schools</td>
<td>K-12 Schools in British Columbia including public, independent, private, and First Nations schools.</td>
</tr>
<tr>
<td>Non-Mathematics Subject Specialist Teachers</td>
<td>Certified teachers in British Columbia who did not possess a major or minor in mathematics or degree with significant mathematics content such as engineering or physics prior to teaching secondary mathematics in British Columbia schools.</td>
</tr>
<tr>
<td>Professional Learning Activities</td>
<td>Specific activities non-mathematics subject specialist teachers participate in to strengthen their mathematics content knowledge.</td>
</tr>
<tr>
<td>Secondary Mathematics</td>
<td>Mathematics courses taught in BC schools from Grades 8 to 12.</td>
</tr>
<tr>
<td>Self-Directed Learning</td>
<td>“Individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes” (Knowles, 1975, p. 18).</td>
</tr>
<tr>
<td>Subject Matter Content Knowledge</td>
<td>“The amount and organization of knowledge per se in the mind of the teacher” (Shulman, 1986, p. 9) in a given subject area.</td>
</tr>
<tr>
<td>Types of Professional Learning</td>
<td>There are four types of professional learning based on Grow’s (1991) stages of self-directed learning: Autodidactic, Learning Communities, Traditional Professional Development, and Formal.</td>
</tr>
</tbody>
</table>
Chapter 1.  Background to the Study

1.1. Introduction

Teachers without a formal background in mathematics can be assigned to teach secondary mathematics (Grades 8 to 12) in British Columbia (BC) schools. This is known as out-of-field teaching: “teachers assigned to teach subjects for which they have little training or education” (Ingersoll, 1999, p. 26). According to the 2000 Survey of Recent Graduates of BC Teacher Education Programs, “5.6% of respondents indicated that they had a major, minor or concentration in mathematics. However, 17.7% of respondents suggested that they taught mathematics regularly” (British Columbia College of Teachers [BCCT], 2001, p. 7). Out-of-field teaching in secondary mathematics was confirmed in the 2002 Recent Graduates survey where 60 out of 130 (or 46.2%) of the survey participants were teaching secondary mathematics out-of-field (BCCT, 2004). Mathematics had the second highest percentage of teachers teaching out-of-field next to computer science (BCCT, 2004). On the other hand, the subject areas of English, Social Studies, Biology, and History had no out-of-field teachers and revealed an oversupply of teachers with a major or minor in those subject areas (BCCT, 2004). School principals are tasked annually with the responsibility of staffing schools and assigning teachers to classes they will teach in the new school year. In making these decisions, school principals are constrained by factors such as teacher seniority, availability of subject specialist teachers, the collective agreement, student enrolment, class size guidelines, and cost effectiveness (Ingersoll, 2002). As a result, some teachers within a school may be assigned to teach secondary mathematics as out-of-field teachers.

To become a teacher in BC, applicants are required to have at least one teachable minor. A teachable minor requires 18 upper-level credits in a subject area
taught in BC schools. Secondary teacher candidates are required to complete at least 24 credits in a teachable subject area (BC Ministry of Education, 2016a) before entering teacher education. Coursework completion suggests subject matter preparation. Coursework is completed “in sufficient depth to ensure appropriate knowledge and understanding of the subject” (BC Ministry of Education, 2016b, p. 15). Applicants lacking subject area credits in a teachable subject area would not be admitted into a BC teacher education program. To qualify to become a secondary teacher in secondary mathematics, at least 24 credits in university mathematics must be completed with a minimum grade of C+; where 18 credits at the 300- or 400-level constitutes a teachable minor and 30 credits a teachable major (Professional Development Program [PDP at SFU], n.d.; Teacher Education Office [TEO at UBC], n.d.; UFV, n.d.; UNBC, n.d.; UVic, n.d.).

Secondary mathematics teacher candidates must have completed a teachable minor or major in mathematics before entering the BC teacher education program. Upon certification, secondary mathematics teacher candidates would have the intention of becoming practicing secondary mathematics teachers in BC schools. However, teachers who achieve a professional certificate in BC are certified to teach any subject at any grade level (BC Ministry of Education, 2017a). There are no restrictions. Although practicing secondary mathematics teachers would be expected to have completed the coursework in university mathematics as required by BC teacher education programs, certified teachers without a mathematics-subject specialty were teaching secondary mathematics in BC schools (BCCT, 2001, 2004). The practice of having out-of-field secondary mathematics teachers is not isolated to BC schools. According the School Achievement Indicators Program (SAIP) 2001 on mathematics for 13- and 16-year-olds in Canada, “less than 40% of [the participating students’] teachers hold a mathematics degree or one with substantial mathematics content” (Council of Ministers of Education [CMEC], 2003, p. 111).

Out-of-field teaching in secondary mathematics also existed outside of Canada. The Schools and Staffing Survey from the United States indicates that 33.1% of mathematics teachers teaching Grades 7 to 12 do not have a major or minor in mathematics or a degree with significant mathematics content (Ingersoll, 2002). In Australia, approximately 30% of Grades 11 and 12 mathematics teachers and 46% of
Grades 7 to 10 mathematics teachers do not have credit in any third- or fourth-year university mathematics courses (McKenzie, Kos, Walker, & Hong, 2008). This teacher statistic improved over time in Australia. Six years later, 28% of Grades 11 and 12 mathematics teachers and 40% of Grades 7 to 10 mathematics teachers had qualifications with less than third-year university mathematics courses (McKenzie, Weldon, Rowley, Murphy, & McMillan, 2014). Mathematics teachers in Ireland who taught 12- to 18-year-old students were surveyed about their training and qualifications. "[Forty-eight percent] of the teachers sampled did not possess a teaching qualification in mathematics" (Riordain & Hannigan, 2011, p. 296). Yet 78% of these unqualified teachers believed they had adequate qualifications to teach mathematics (Riordain & Hannigan, 2011).

Subject matter preparation by teacher candidates prior to teacher education contributes to the candidates’ subject matter content knowledge. Shulman (1986) defined and subdivided teacher content knowledge into three categories: subject matter content knowledge, curricular knowledge, and pedagogical content knowledge. Subject matter content knowledge is “the amount and organization of knowledge per se in the mind of the teacher” (p. 9) that “requires going beyond knowledge of the facts or concepts of a domain” (p. 9). Subject matter content knowledge in mathematics includes algorithms, definitions, and facts in addition to a conceptual understanding of the subject matter (Leinhardt & Smith, 1985; Ma, 2010). Subject matter preparation in mathematics would have been completed in university as a major or minor prior to entering BC teacher education for secondary mathematics subject specialists. “Teacher knowledge should go beyond an awareness of the material to be mastered by students” (Krauss, Brunner, Kunter, & Jordan, 2008, p. 717).

Curricular knowledge is the understanding of “the full range of programs designed for the teaching of particular subjects and topics at a given level” (Shulman, 1986, p. 10) and the “variety of instructional materials available in relation to those programs” (p. 10). Curricular knowledge includes understanding the contents of the curriculum and learning resources that are suitable for a particular course or grade level. This knowledge extends to different grade levels that precede and follow the course being taught. Curricular knowledge focuses on the curriculum as prescribed by the ministry whereas pedagogical content knowledge focuses on subject specific pedagogy.
Pedagogical content knowledge as defined by Shulman (1986) is a combination of both pedagogy and content and "goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching" (p. 9), that is, finding "ways of representing and formulating the subject that make it comprehensible to others" (p. 9). This includes knowing what makes a topic easy or difficult to learn, recognizing and anticipating preconceptions and misconceptions of learners, and implementing appropriate teaching strategies to resolve these misunderstandings (Shulman, 1986). Pedagogical content knowledge is the understanding of pedagogy that is specific to a curricular area, such that it would differ for different subject areas.

Ball, Thames, and Phelps (2008) examined Shulman’s (1986) definitions of subject matter content knowledge and pedagogical content knowledge further and sub-divides each category into three domains (Figure 1.1). Subject matter knowledge is subdivided into common content knowledge, horizon content knowledge, and specialized content knowledge. Common content knowledge is “the mathematical knowledge and skill used in settings other than teaching” (Ball et al., 2008, p. 399). This knowledge includes understanding the material that is taught to and learned by students, knowing what is mathematically correct or incorrect, and using correct terminology and notation. Common content knowledge is not unique to teaching mathematics (Ball et al., 2008).

Specialized content knowledge is “the mathematical knowledge and skill unique to teaching” (Ball et al., 2008, p. 400). Specialized content knowledge goes beyond the tacit understanding of mathematics and doing the mathematics required by students. Teachers must be able to unpack the content to make it explicit or visible to students so that they can develop an understanding and fluency of the content (Ball et al., 2008). Decompressed knowledge is not a conceptual understanding of mathematics, but a firm grasp of the content specialized for teaching (Ball et al., 2008). Specialized content knowledge does not depend on knowledge of students or teaching, like pedagogical content knowledge does; moreover, specialized content knowledge is gained from the practice of teaching mathematics, not from university (Ball et al., 2008).
The third domain of subject matter knowledge is horizon knowledge. Horizon knowledge is "an awareness of how mathematical topics are related over the span of mathematics included in the curriculum" (Ball et al., 2008, p. 403), which is similar to Shulman’s (1986) curricular knowledge. Horizon knowledge is about looking at the content a few grades ahead and deciding how to teach the content in the assigned grade level. For this reason, horizon knowledge is categorized under the subject matter content domain and under the pedagogical content knowledge domain as knowledge of content and curriculum showing the connection between curriculum and teaching.

Ball et al. (2008) subdivided pedagogical content knowledge into three domains: knowledge of content and students, knowledge of content and teaching, and knowledge of content and curriculum (see Figure 1.1). Knowledge of content and students is anticipating or predicting common mistakes or misunderstandings that students might make given a particular mathematics concept or procedure (Ball et al., 2008). Knowledge of content and teaching is the intersection between understanding a given mathematical concept and pedagogy and the pedagogical issues specific to that concept.
that might affect student learning (Ball et al., 2008). Knowledge of the content and curriculum, as mentioned earlier, is similar to horizon knowledge where understanding what needs to be taught and what will be taught influences how content is taught to students.

This study focused on non-mathematics subject specialist teachers (NMSSTs) who teach or have taught secondary mathematics in BC schools, the subject matter content knowledge of NMSSTs in mathematics, and their professional learning experiences. NMSSTs are certified teachers who did not complete a degree in mathematics or a degree with significant mathematics content prior to teaching secondary mathematics. NMSSTs who are assigned to teach secondary mathematics are likely to spend some time learning or relearning subject matter to teach mathematics. The content knowledge in question is subject matter content knowledge of NMSSTs. In this study, Shulman’s (1986) definition of subject matter content knowledge, separate from pedagogical content knowledge and curricular knowledge, was emphasized. Moreover, subject matter content knowledge was not subdivided into different domains in this study as described by Ball et al. (2008). Subject matter content knowledge was undifferentiated. BC schools considered were public, independent, private, and First Nations schools.

1.2. Statement of the Problem

The problem is captured in part by Berliner’s observation that, “expert teachers of social studies are not automatically going to transfer their expertise to the teaching of mathematics” (Berliner, 1991, p. 147). NMSSTs have little or no subject matter preparation in mathematics. They may have varying amounts of content knowledge (Leinhardt, & Smith, 1985; Ma, 2010), but “without solid support from subject matter knowledge, promising methods or new teaching conceptions cannot be successfully realized” (Ma, 2010, p. 38). "Knowing the subject matter terrain, in a variety of ways, is the foundation for pedagogical content knowledge. Effective teachers need subject matter competence” (Grossman, Scheonfeld, & Lee, 2005, pp. 204-205). Knowing whether a topic is central or peripheral to the discipline is important to making good pedagogical judgements (Shulman, 1986). “Teachers who do not themselves know a
subject well are not likely to have the knowledge they need to help students learn this content” (Ball et al., 2008, p. 404).

“Highly qualified teachers actually become highly unqualified if they are assigned to teach subjects for which they have little training or education” (Ingersoll, 2001, p. 42). Knowing how to do mathematics, asking questions to get the right answers, or showing how to solve problems (Ball, 1988) exemplifies the front-stage behaviours of teaching mathematics (Ball, 1988). “Teachers must know the subject they teach” (p. 404). Although acquiring a deep understanding of mathematics does not guarantee good teaching in mathematics (National Research Council, 2000), “it is not possible to teach mathematics without having enough knowledge about the subject” (Turnuklu & Yesildere, 2007, p. 9). NMSSTs as out-of-field teachers lack the formal subject matter preparation in mathematics prior to teaching secondary mathematics and must learn or relearn the subject matter as practicing secondary mathematics teachers.

1.3. Purpose of the Study

The purpose of this study was to identify the professional learning activities that NMSSTs participate in to strengthen their mathematics content knowledge. By determining which learning activities these teachers participate in, value most, and believe help them to acquire the subject matter and teach mathematics better, professional learning programs can be created within schools, school districts, or outside institutions to support NMSSTs with their subject matter development. Identifying which professional learning activities helped NMSSTs can inform policy-makers, school district decision-makers, school principals, and teacher leaders about what learning activities strengthened the mathematics content knowledge of NMSSTs. This is one possible strategy to improve the quality of teaching of NMSSTs and thus student achievement in secondary mathematics. Schools or school districts can therefore develop programs to support the professional learning and subject matter development of NMSSTs locally. The results can also inform out-of-field teachers in general about which professional learning activities to participate in to gain subject matter content knowledge.
1.4. Research Question

The research question for this study is:

- What professional learning activities have non-mathematics subject specialist teachers who teach or have taught secondary mathematics in British Columbia schools participated in to gain subject matter content knowledge in mathematics?

Sub-questions to support the research question are:

1. Which professional learning activities do these teachers believe best facilitated their acquisition of subject matter content knowledge in mathematics?
2. Which professional learning activities, in gaining subject matter content knowledge in mathematics, do these teachers believe helped them to teach secondary mathematics better?

1.5. Significance of the Study

Out-of-field teaching has not been explored extensively in BC. Aside from the survey data collected from the BC College of Teachers in 2000 and 2002 (BCCT, 2001 and 2004, respectively) there is no recent data gathered to reveal the extent of out-of-field teaching in BC schools. This study indicates the continued practice of out-of-field teaching in secondary mathematics and also which professional learning activities NMSSTs participate in to gain subject matter content knowledge in mathematics. To participate in the study, a teacher had to self-identify as teaching secondary mathematics out-of-field in a BC school and having participated in professional learning to strengthen mathematics content knowledge. General characteristics describing NMSST participants in this study were identified.

Literature on out-of-field teaching in secondary mathematics was predominantly from out of province (Ingersoll, 1999, 2001, 2002; McConney & Price, 2009; Riordan & Hannigan, 2011). It discusses the problem of out-of-field teaching, why it exists, and initiatives implemented or recommended to address the problem. This study focused on BC schools, out-of-field secondary mathematics teachers, and the professional learning activities these teachers participate in to gain subject matter content knowledge in
mathematics. Frequency of participation, perceived value, and deemed helpfulness of each learning activity were assessed to determine which learning activities are worthwhile for NMSSTs to participate in for subject knowledge development.

Strengthening the subject matter content knowledge in mathematics for NMSSTs would enable these teachers to develop pedagogy specific for mathematics since “pedagogical content knowledge is influenced by subject matter knowledge” (Even, 1993, p. 97). The quality of teaching of secondary mathematics for NMSSTs can improve because “the quality of mathematics teaching depends on teachers’ knowledge of the content” (Ball, Hill, & Bass, 2005, p. 14).

Teacher effectiveness has a direct effect on student achievement. “The single most dominant factor affecting student academic gain is teacher effect” (Sanders & Rivers, 1996, p. 6). The effects are additive and cumulative, with little evidence of compensatory effects (Sanders & Rivers, 1996; Wright, Horn, & Sanders, 1997). One characteristic contributing to teacher effectiveness is subject matter competency.

A growing body of research provides convincing evidence that what teachers know and believe about mathematics is closely linked to their instructional decisions and actions…. (National Research Council, 2000, p. 164)

Lachner and Nückles (2016) compared mathematics researchers to experienced mathematics teachers in terms of instruction and student achievement. They concluded that the Grade 11 students taught by mathematics researchers outperformed the students taught by the experienced mathematics teachers. Mathematics researchers with PhDs in mathematics were rich in content knowledge and had a deep understanding of the subject matter. Because of this, mathematics researchers taught mathematics that was process-oriented and focused on the why of mathematics. On the other hand, the experienced mathematics teachers were rich in pedagogical content knowledge. They taught mathematics that was product-oriented and focused on getting the right answer. This shows that student achievement improved when instruction of the content was process-oriented versus product-oriented. Overall, both the groups of students taught by researchers and those taught by teachers experienced learning
gains, whereas the group of students in this study with the lowest learning gains was students who were offered no explanation.

Hill, Rowan, and Ball (2005) conducted a large-scale, empirical study on the effects of teachers’ mathematics knowledge for teaching on student achievement over a 3-year period with Grades 1 and 3 teachers and students. The study focused on specialized mathematical content knowledge and skills. Although the focus of the study was at the primary grades, the results showed that “teachers’ mathematics knowledge for teaching positively predicted student gains in mathematics achievement” (p. 400). Content-focused professional development or pre-service programs intended to improve mathematics knowledge improved student achievement as intended (Hill et al., 2005).

The significance of the study was to provide current data on out-of-field teaching in secondary mathematics in BC schools, describe NMSSTs participating in this study, and identify what professional learning activities NMSST participated in to strengthen their mathematics content knowledge as practicing secondary mathematics teachers.

1.6. Delimitations

Delimitations of the study are as follows:

1. Responses given by participants who were disqualified from participating in the survey questionnaire were not analysed with one exception. Participants noting they had a mathematics intensive degree on the survey questionnaire, in Section 1: Participant Profile, were asked to specify that degree before exiting the survey.

2. Only 16 professional learning activities were surveyed, although respondents could identify other learning activities in open-ended sections of the survey. The content respondents actually learned during these learning activities and pedagogical development was not measured in this study.

3. This study excluded formally trained secondary mathematics teachers, but included NMSSTs who received formal training during or after teaching secondary mathematics in BC schools.

4. This study did not contact any of the participants for further questioning or interviews. Participants were anonymous.

5. This study focused on which professional learning activities NMSSTs participated in to gain subject matter knowledge, not why.
6. Subject matter knowledge was not subdivided into two domains of common content knowledge and specialized content knowledge.

1.7. Limitations

Limitations of this research study are as follows:

1. The population of NMSSTs practicing in BC schools was unknown.
2. Potential participants were required to self-identify as NMSST to participate.
3. Non-probability sampling methods were utilized. Findings derived from this study cannot be generalized to the population of NMSSTs.
4. Surveys were distributed online for a 2-week period. Not all NMSSTs had online access or were contacted to participate. The number of participants was limited.
5. The survey questionnaire could be completed more than once on the same computer. This allowed multiple teachers from the same school to participate. It was assumed that each NMSST participated once.
6. Participants may not have accurately described their professional learning experiences on the online survey questionnaire. Questions may have been misunderstood, and responses to questions may not have been truthful.

1.8. Organization of the Study

The organization of this study is based on a 6-chapter framework. Chapter 1 is the “Background of the Study” where the introduction, statement of the problem, research questions, purpose of the study, and significance of the study are described. Chapter 2 is the “Literature Review,” which synthesizes the literature on learning subject matter, teachers as learners, and stages of self-directed learning. Chapter 3 is the “Design of the Study” where the methodology, participant selection, instrumentation, data-collection procedures, and data analysis for descriptive research are described. Chapter 4 is “Data Analysis.” Key findings, correlations, and trends are highlighted to indicate which professional learning activities NMSSTs participated in to strengthen their mathematics content knowledge and other univariate and bivariate data analysis are presented to describe the professional learning experiences of NMSSTs in this study.
Chapter 5 is the “Discussion” where key findings of the study and how they are connected to or disconnected from the big ideas from the literature review are discussed. Furthermore, the research question and sub-questions of the study are answered in Chapter 5. Finally, Chapter 6 is the “Conclusions” where recommendations are made for the practitioner, school leadership, and future research based on the findings and content from the literature review.
Chapter 2. Literature Review

What professional learning activities have non-mathematics subject specialist teachers (NMSSTs) who teach or have taught secondary mathematics in British Columbia (BC) schools participated in to gain subject matter content knowledge in mathematics? The literature review highlights qualities of professional development, teachers as learners, opportunities to strengthen mathematics content knowledge for teachers, experiential learning, expertise versus experience, and stages of self-directed learning. The intent of this literature review is to focus on the professional learning experiences of NMSSTs and how NMSSTs acquire mathematics content knowledge on the job as practicing secondary mathematics teachers. Teachers who do not have a formal background in mathematics and who are assigned to teach secondary mathematics are discussed in this literature review. Examples are drawn from other jurisdictions.

2.1. Learning Subject Matter

Teachers as learners gain knowledge in a variety of ways. They can learn from their own teaching practice, interactions with colleagues, teacher educators, graduate programs, and events that are separate from their professional work (National Research Council, 2000). Professional learning activities could be action research, apprenticeship, mentoring, in-service education workshops, meetings with professional associations, teacher-enhancement programs, a masters degree, continuing education courses, computer-based learning, parenting or coaching (National Research Council, 2000).

Teachers, like students, engage in four types of learning environments: learner-centered, knowledge-centered, assessment-centered, and community-centered (National Research Council, 2000). Learner-centered environments “build on strengths,
interests, and needs of the learners” (p. 192). Knowledge-centered environments strengthen the learner’s knowledge (National Research Council, 2000). Assessment-centered environments “provide opportunities for learners to test their understanding by trying out things and receiving feedback” (p. 196). Community-centered environments “involve norms that encourage collaboration and learning” (p. 197). Qualities of all four types of learning environments can be found in the professional learning activities teachers choose to participate in. Some qualities may be emphasized more than others depending on the context of the professional learning activity.

Research suggests that high-quality professional development is structured as ongoing collaboration amongst teachers with an explicit goal of improving student achievement, student learning, and curriculum and pedagogy. Professional development gives teachers access to alternative ideas and methods to try out and to observe (Garet, Porter, Desimone, Birman, & Yoon, 2001). A key characteristic is the duration and contact time teachers have to learn together, participate collectively, and develop a culture of learning (Garet et al., 2001; Hill & Ball, 2004; Loucks-Horsley & Matsumoto, 1999).

Despite this research, most teachers attended traditional professional development such as workshops and conferences (Loucks-Horsley & Matsumoto, 1999). These learning activities tend to be short-term, one-time sessions that are held offsite from where teachers teach. As a result, there is a disconnection from teaching practice. The fact that participants may not come from the same school or teach the same grade level forms a barrier to ongoing, collaborative professional learning amongst participants. Moreover, conferences and workshops tend to focus on pedagogy disconnected from practice and do not provide opportunities for teachers to work and learn with each other (Garet et al., 2001; Loucks-Horsley & Matsumoto, 1999).

Non-traditional forms of professional development occur over longer periods of time to enable teachers as learners to delve deeper into the subject matter, build relationships with colleagues, experiment and gather feedback, create a learning community, and have in-depth discussions on student misconceptions and pedagogy (Garet et al., 2001; Hill & Ball, 2004; Loucks-Horsley & Matsumoto, 1999). Such professional development embodies the principles of learning, which include “active
engagement, learning over time, and opportunities to practice and apply what is learned” (Loucks-Horsley & Matsumoto, 1999, p. 263). Examples of non-traditional professional development are teacher study groups, mentoring, teacher networks, committees, internships, and collaborative research (Garet et al., 2001). Effective professional development that results in more enduring learning with a community of learners includes active learning, reflective learning, collaboration, and supportive learning communities or culture (Shulman & Shulman, 2004).

An expert to guide, mentor, and share expertise can also help NMSSTs to gain subject matter knowledge in mathematics as practicing secondary mathematics teachers (National Research Council, 2000). Working and learning separate from others in an egg-carton-like teaching structure in schools creates challenges for sense-making (Spillane, Reiser, & Gomez, 2006). Effective professional learning activities include instructional staff who are highly knowledgeable and focused on the mathematical content itself, teachers who are actively learning and working together, and teachers learning content that is related to their practice (Garet et al., 2001; Hill & Ball, 2004).

The following sections present examples of practicing mathematics teachers who participated in professional learning activities to gain subject matter content knowledge in mathematics. Two of the three examples involve secondary mathematics teachers and one example involves elementary teachers. As mentioned in Chapter 1, this study is focused on the subject matter content knowledge of NMSSTs. Therefore, mathematics content knowledge in this study refers to subject matter content knowledge in mathematics as defined by Shulman (1986); and does not refer to Ball et al.’s (2008) definition, which includes both subject matter content knowledge and pedagogical content knowledge that are sub-divided into the three domains (see Figure 1.1).

2.1.1. System change

The Australian government responded to the out-of-field teaching phenomenon in mathematics in Western Australia with two initiatives. The first initiative dealt with the number of students enrolling in university-mathematics programs. To attract more students to enrol in university-mathematics programs and increase the likelihood that more mathematics students would become mathematics teachers, the tuition was
lowered (McConney & Price, 2009). The second initiative bridged the 4-year gap of the first initiative with school programs designed to give out-of-field teachers subject matter content knowledge in mathematics (McConney & Price, 2009).

Two school programs were created. One program was designed for early-learning teachers and the other program for junior mathematics teachers to teach senior mathematics (McConney & Price, 2009). The secondary program spanned several months with intensive coursework held once per week after school, in-class projects, and mentorship with currently practicing senior mathematics teachers (McConney & Price, 2009). The junior mathematics teachers participating in the secondary program valued the ongoing dialogue and maintained relationships with their mentor after the program (McConney & Price, 2009). The focus of the program was to broaden and deepen the teachers’ understanding of the subject matter (McConney & Price, 2009).

Many of the participants claimed that the secondary program helped them understand the subject matter better and improved their teaching of junior mathematics (McConney & Price, 2009). Some of the junior mathematics teachers who were assigned to teach senior mathematics after the program ended claimed that they felt more prepared to teach these courses (McConney & Price, 2009). According to these teachers, one of the most valuable aspects of this program was mentorship with experienced senior mathematics teachers (McConney & Price, 2009). With the support and guidance from a mentor, teachers as learners could try out new ideas, create a portfolio of their learning, and take control of their learning (McConney & Price, 2009).

This system-wide reform to address out-of-field teaching in mathematics at the secondary level in Western Australia is an example of how to support the professional learning of NMSSTs in partnership with government, universities, and schools. This initiative implemented a wide variety of professional learning activities with a small cohort of teachers and experts in the field to prepare junior mathematics teachers with the subject matter needed to teach senior mathematics. Different types of professional learning activities were participated in over a significant period to strengthen the mathematics content knowledge of junior mathematics teachers and build capacity.
2.1.2. Profound understanding

Ma (2010) compared the mathematical subject matter knowledge of elementary school teachers from the United States (US) and China. Ma concluded that Chinese teachers were algorithmically competent and possessed very few misconceptions of the subject matter while the US teachers were procedurally focussed and possessed fragmented mathematical knowledge (Ma, 2010). In this study, Chinese teachers wanted to know how to carry out an algorithm and why it worked; they could explain or justify the mathematics verbally and symbolically; they strove to solve problems in multiple ways and to make connections between topics (Ma, 2010). Ma defined this knowledge as a profound understanding of foundational mathematics (PUFM), the foundation for future mathematics. Ma’s study sought to determine how Chinese teachers developed PUFM. She interviewed and compared prospective teachers from China, Grade 9 students from China, and US and Chinese teachers (Ma, 2010).

The mathematical knowledge of Chinese teachers differed dramatically from that of the prospective teachers and Grade 9 students (Ma, 2010). The prospective teachers and Grade 9 students were algorithmically competent, but prospective teachers provided correct answers and showed a concern for teaching and learning whereas the Grade 9 students revealed a broader perspective and tended to make more mistakes (Ma, 2010). Chinese teachers had years of experience, taught all grade levels more than once, and demonstrated a broad, deep, and thorough understanding of the subject matter or PUFM (Ma, 2010). There was no clear line separating teachers with PUFM from those without. PUFM was not acquired through formal education prior to teaching mathematics, but seemed to have developed after one became a teacher (Ma, 2010). Several aspects of the Chinese education system seem to help teachers develop PUFM (Ma, 2010).

An important aspect of the system is intense study of the teaching materials, which includes the act of teaching, teaching round-by-round, and studying the textbook, teacher’s guide, and national curriculum (Ma, 2010). Teachers were learning the subject matter by teaching. The system is designed to have teachers teaching each grade level from Kindergarten to Grade 7 year-by-year in a 7-year cycle known as the round-by-round to become familiar with the subject matter at each grade level (Ma, 2010). Among Chinese teachers, “the most studied material is the textbook. Teachers study and
discuss it during the school year as they are teaching” (p. 142). Teachers studied the national curriculum during the summer before the start of school and referred to the teacher’s guide when necessary (Ma, 2010). Teaching materials were accessible and contained the content needed to teach each course (Ma, 2010).

Teachers learned from other teachers (Ma, 2010). Chinese teachers were organized into “teaching research groups” (p. 136) that met regularly on a weekly basis (Ma, 2010). These teachers studied the teaching materials collectively and were situated in the same office to do so (Ma, 2010). Learning occurred in formal meetings or informal interactions (Ma, 2010). “Not only do young teachers learn mathematics through collegiality, experienced teachers also benefit from it” (p. 137). Teachers also learned from students who were more knowledgeable than the teachers were (Ma, 2010).

Chinese teachers developed PUFM by doing mathematics. “Solving one problem with several ways for them seemed to be an important indicator of ability to do mathematics” (Ma, 2010, p. 140). Chinese teachers were doing mathematics like mathematicians but made clear what they were doing and what they were teaching (Ma, 2010). “Through this interaction, one develops a teacher’s subject matter knowledge” (p. 141). Subject matter knowledge for Chinese teachers was developed through the lens of teaching and learning (Ma, 2010). “Chinese teachers develop and deepen their subject matter knowledge… by preparing for classes, teaching the material, and reflecting on the process” (p. 141).

Although Ma’s (2010) study focused on elementary school teachers, secondary teachers can also participate in similar professional learning activities to develop a profound understanding of secondary mathematics. PUFM is “deep, broad, and thorough” (p. 120). PUFM is more than algorithmic competence: it is the understanding of conceptual structures in mathematics, organization of the content, finding multiple solutions, making relevant connections, and building mathematical attitudes inherent in the subject matter (Ma, 2010). Teachers with PUFM “do not invent connections between and among mathematical ideas, but reveal and represent them in terms of mathematics teaching and learning” (p. 122).
2.1.3. Higher education

Universities offer graduate programs in mathematics education or numeracy for practicing mathematics teachers. These programs are designed for those who teach mathematics at all grade levels and seek additional credentials as they further their understanding of mathematics in education. Graduate programs include diploma programs, master degrees, and doctoral degrees. Participating in higher education programs not only provides practicing teachers with a deeper understanding of the subject matter as it relates to teaching, but also immerses these teachers in continuous learning of the subject matter in a meaningful way, either engaged in research or academic inquiry, with a cohort of like-minded individuals for at least a 2-year period.

Recognizing that mathematics teachers do not require the same mathematical knowledge as mathematicians or mathematics-related professions, Papick (2011) described two collaborative mathematics projects between schools and universities designed to strengthen the mathematics content knowledge of middle and secondary teachers. “Mathematics teachers should deeply understand the mathematical ideas… that are central to the grade levels they will be teaching and be able to communicate these ideas in a developmentally appropriate manner” (p. 389).

The first collaboration was connecting middle-school mathematics teachers with college mathematics educators where course materials were designed to provide middle school teachers with a strong foundation in mathematics (Papick, 2011). Teachers who participated in this program earned credits towards a university certificate program (Papick, 2011). In this collaboration, “the continual process of connecting what they are learning in the college classroom to what they will be teaching in their own classrooms provide[d] teachers with real motivation to strengthen their mathematical content knowledge” (p. 391).

The second collaboration involved mathematicians, mathematics educators, classroom teachers, statisticians, and cognitive psychologists co-designing a 9-credit-hour course for Algebra 1 teachers, with the goal of helping teachers to become master Algebra 1 teachers emphasizing algebraic thinking and content knowledge for middle and high school students (Papick, 2011). “The Algebra for Algebra Teachers course was designed to help teachers better understands the conceptual underpinnings of school
algebra and how to leverage that understanding into improved classroom practice” (p. 392). The course was a 2-week summer intensive course that was followed up with support from an instructional coach during the school year to help transfer the knowledge learned from the summer to the classroom (Papick, 2011). The objective of this collaboration was to heighten the subject matter content knowledge of secondary mathematics teachers with the support and guidance of experts in the field.

A province-wide initiative focused on Kindergarten to Grade 12 (K-12) mathematics education in Ontario is another example where higher education is part of the professional learning experience of mathematics teachers that deepens their understanding of the subject matter. The Ontario Ministry of Education invested $60 million dollars in “A Renewed Math Strategy for Ontario,” “helping students gain the math knowledge and skills they will need for the future” (Ontario Ministry of Education, 2016, para. 1). Some of the key elements found in this K-12 mathematics-education strategy included “opportunities for educators to deepen their knowledge, including a dedicated Professional Development Day... coaching for principals of select secondary schools to lead improvement... [and] up to three math lead teachers in all elementary schools” (“Strategy At-A-Glance,” 2016, Bullet 7).

Embedded in the Ontario strategy was an increase of professional learning time for teachers and principals to deepen their understanding of mathematics learning and teaching (Ontario Ministry of Education, 2016). Mathematics lead teachers in elementary schools are responsible for deepening their mathematics knowledge and transferring this learning into the classroom. A dedicated mathematics facilitator works with schools of greatest need, and there are courses available for teachers and principals to acquire additional qualifications taken as school-based teams (Ontario Ministry of Education, 2016). This initiative focuses on the subject matter content knowledge development for teachers, school administrators, and teacher leaders, and professional development is an integral part of improving and modernizing mathematics education for K-12 students.
2.2. Teachers as Learners

“It can be difficult for teachers to undertake the task of rethinking their subject matter. Learning involves making oneself vulnerable and taking risks, and this is not how teachers often see their role” (National Research Council, 2000, p. 195). NMSSTs are not formally trained to be mathematics subject specialists prior to teaching secondary mathematics. These teachers will learn or relearn some mathematics as part of their professional learning. New NMSSTs will have limited time to gain the subject matter over the summer months while experienced NMSSTs might have participated in several professional learning activities and learned the subject matter on the job.

“Teachers gain new knowledge and understanding… by living the practical experiments that occur as part of professional practice (Dewey, 1963; Schön, 1983)” (National Research Council, 2000). This section of the literature review looks at teachers as learners and how teachers are reflecting in action and reflecting on action to gain professional knowledge in the context of strengthening their mathematics content knowledge (Schön, 1983). The learning process is cyclical and this section considers how teachers learn from experience and build expertise from deliberate practice. Time and action on part of the learner are essential for NMSSTs to gain subject matter knowledge.

2.2.1. Experiential learning

Simply stated, experiential learning is learning from experience. Kolb (1984) describes four stages of the experiential learning cycle: (a) concrete experience, (b) reflective observation, (c) abstract reconceptualization, and (d) active experimentation. The experiential learning cycle begins with a problem or a surprise (Schön, 1983). This is the concrete experience. Problems found in professional practice are complex, uncertain, unstable, unique, and value-conflicted (Schön, 1983, 1987). Some problems cannot be solved with technical rationality where the solution is simply derived from science and empirical evidence (Schön, 1983). Sometimes the problem is messy rather than straightforward. The concrete experience or problematic situation in this case is NMSSTs not having the subject matter content knowledge in mathematics to teach secondary mathematics. The problem or surprise might arise when the position is
assigned, when a question comes from a student in the classroom, or as an unfamiliar mathematics topic.

The second stage of the experiential-learning cycle is called reflective observation (Kolb, 1984). It is how the problem is defined and framed to find a solution (Schön, 1983, 1987). Problems faced in professional practice are often divergent (Schön, 1983, 1987), and one cannot always follow a well-established, clear set of rules that lead to a singular solution. NMSSTs may realize the problem in the context of subject matter content knowledge and attempt to figure out how to frame the problem to come to a resolution. Reflection-in-action is tacit knowing, “implicit in our patterns of action and in our feel for the stuff with which we are dealing” (Schön, 1983, p. 49). Feedback from a student, parent, colleague, mentor, or school principal, can lead teachers as learners to reflect on action or reflect in action. Reflecting on action is looking back on what was done. Reflecting in action is “learning by doing” where “reflection tends to focus interactively on the outcomes of action, the action itself, and the intuitive knowing implicit to the action” (p. 56). Prompted by feelings of uncertainty or unease, new information about the problem is acquired (Osterman & Kottkamp, 1993), which may provoke NMSSTs as experiential learners to proceed to the next stage of the experiential-learning cycle.

The third stage of Kolb’s (1984) experiential-learning cycle is abstract reconceptualization. At this stage, NMSSTs consider new ideas or new strategies to adopt into their practice (Osterman & Kottkamp, 1993). Faced with the dilemma of “rigor or relevance” (Schön, 1983, p. 42), teachers as learners take action to investigate the problem further to determine an appropriate solution. The rigor is returning to technical rationality and referring to pure mathematics to address the problem, but the relevance or practicality of the situation suggests that the problem has more to do with mathematics as it relates to teaching, not the discipline (Schön, 1983, 1987). NMSSTs may choose to participate in a professional learning activity to develop a conceptual understanding of the subject matter or to understand the subject matter algorithmically (Schön, 1983, 1987).

The experiential-learning cycle concludes with active experimentation. Teachers as learners implement what was learned as reconceptualized behaviour (Osterman &
Kottkamp, 1993), thus the experiential learning cycle renews itself with a new concrete experience. NMSSTs gain subject matter content knowledge from experience on the job teaching secondary mathematics, as did the elementary school teachers from China who developed their profound understanding of fundamental mathematics from teaching mathematics and intensely studying the teaching materials (Ma, 2010).

### 2.2.2. Teaching expertise

Berliner (2001) defined deliberate practice as a lesson confined to teacher education or training that occurs outside the classroom. For NMSSTs, this could be university course work, attending conferences or workshops, or doing mathematics from a textbook or in the workplace. However, Ericsson and Pool (2016) defined deliberate practice as having the opportunity to “try different things in different situations, get feedback on their performance, and then apply what they have learned” (p. 116). For NMSSTs, this could be learning the subject matter from teaching the subject matter, solving mathematics problems from a textbook with an expert in the field, or learning within a professional learning community or study group. Deliberate practice is designed with the intent of improving, supported by the guidance and feedback of experts in the field (Ericsson & Pool, 2016). “Doing the same thing over and over again exactly in the same way is not a recipe for improvement: it is a recipe for stagnation and gradual decline” (p. 121). Ericsson and Pool’s definition for deliberate practice aligns itself with Kolb’s (1984) Experiential Cycle. Learners are provided with “the opportunity to try different things and make mistakes without fatal consequences, to get feedback and figure out how to get better, and then put their lessons to the test the next day” (Ericsson & Pool, 2016, p. 119). The cycle of deliberate practice repeats itself over and over until a level of expertise is obtained.

With opportunities for deliberate practice in the workplace, NMSSTs can develop their teaching expertise and subject matter content knowledge over time. “A reasonable estimate for expertise to develop in teaching, if it ever does, is five or more years” (Berliner, 2001, p. 479). Deliberate practice works best when learners are pushed out of their comfort zones in a feedback-driven practice leading to improvement (Ericsson & Pool, 2016). The goal of deliberate practice in developing expertise is automaticity (Berliner, 2001). Automaticity “allows cognitive resources to be reinvested in other and
higher level of cognitive activity” (p. 474). Developing a deeper understanding of the subject matter creates a solid foundation for pedagogical content knowledge development in secondary mathematics (Shulman, 1986, 1987).

Expertise develops over time with experience and in stages: novice, advanced beginner, competent performer, proficient performer, and expert (Berliner, 2004). “The novice is deliberate, the advanced beginner insightful, the competent performer rational, and the proficient performer intuitive” (p. 207). The expert is able to make meaningful patterns and be flexible with the subject matter because of a depth of understanding (National Research Council, 2000). Very few teachers become experts in teaching while most teachers are likely to become advanced beginners (Berliner, 2004). “Unless you are using practice techniques specifically designed to improve those particular skills, trying hard will not get you very far” (Ericsson & Pool, 2016, p. 122). NMSSTs are tasked with strengthening their mathematics content knowledge and applying this knowledge in the act of teaching the subject matter. Most teachers’ mathematics content knowledge influences how they teach the content (Ball, 1988). Berliner’s (2004) descriptions of each stage are used to describe teaching expertise. They also describe subject matter expertise, as discussed in Chapter 3 (see Section 3.4) on developing the survey instrument.

The novice teacher, the first stage of expertise, teaches mathematics with context-free rules (Berliner, 2004). These teachers are rational and relatively inflexible because they are rule-followers (Berliner, 2004). The advanced beginner has some experience and has developed some strategic and case knowledge that goes beyond context-free rules, but he or she “still has no sense of what is important” (Berliner, 1988, p. 3). The competent performer, the next stage of expertise, has 3 to 5 years of experience, has developed case knowledge, and takes full responsibility for instruction (Berliner, 2004) by making conscious choices and sensible decisions on curriculum and instruction. Competent performers are “not yet fast, fluid or flexible in their behaviour” (Berliner, 1988, p. 4), but they are metacognitive in their practice. Competent performers can approach a new situation flexibly. Proficient performers have more than 5 years of experience, are intuitive in pattern recognition of the course content, and are guided by their know-how and experience (Berliner, 2004). The last stage of expertise is expert.
Expert teachers are fluid within their actions, have a holistic way of viewing situations and are rich in case knowledge (Berliner, 2001).

The development and deepening of mathematics content knowledge should be built on a solid foundation of mathematics competence and understanding (Ball et al., 2008; Ma, 2010; Leinhardt & Smith, 1985). Being algorithmically competent in secondary mathematics does not equate to being conceptually competent and having the appropriate attitudes to promote mathematics learning (Ball, 1988). NMSSTs need to broaden their understanding from algorithmic to conceptual (Leinhardt & Smith, 1985). However, there is no clear division distinguishing common content knowledge from specialized content knowledge (Ball et al., 2008; Hurrell, 2013). It would be difficult to determine if NMSSTs are gaining subject matter knowledge in a superficial way using algorithms or in a deeper way looking for connections and the why (Hurrell, 2013).

2.2.3. Expertise versus experience

Teachers and school leaders are expected to know what students should be able to do, understand, and consider (Hattie, 2012). There is very little difference between the “surface level achievement” (p. 29) of students in mathematics when taught by expert teachers or experienced teachers (Hattie, 2012). However, “students who are taught by expert teachers exhibit an understanding of concepts targeted in the instruction that is more integrated, more coherent, and at a higher level of abstractions” (p. 30). Students taught by expert teachers demonstrated a deeper understanding of the subject matter (Hattie, 2012).

Expert and experienced teachers do not differ in the amount of knowledge they possess (Hattie, 2012), but “experts appear to possess an efficient organization of knowledge with meaningful relations among related element clustered into related units that are governed by underlying concepts and principles” (National Research Council, 2000, p. 38). “Expert teachers have high levels of knowledge and understanding of the subjects that they teach” (Hattie, 2012, p. 24). They are “able to fluently access relevant knowledge because their understanding of subject matter allows them to quickly identify what is relevant” (National Research Council, 2000, p. 17). Expert teachers have a deep understanding of the subject matter and can organize their understanding of the subject
matter differently and apply it differently from experienced teachers (Hattie, 2012). Expert teachers notice meaningful patterns of information, apply knowledge beyond the facts and propositions, and can retrieve aspects of their knowledge with little effort (National Research Council, 2000).

According to Hattie (2012), “students of expert teachers are much more adept at deep, as well as surface, understanding, whereas experienced non-experts are as adept at surface, but not deep, learning” (p. 30). As a result, students taught by expert teachers were three times more likely to achieve deep learning of the content in comparison to students taught by experienced teachers (Hattie, 2012). Riordain and Hannigan (2011) argue, “qualified mathematics teachers play a significant role in improving the quality of mathematics learning at post-primary level” (p. 299; e.g., 12- to 18-year-old students). In Ireland, post-primary students were underperforming in mathematics (Riordain & Hannigan, 2011). One possible factor contributing to this underperformance was teacher qualifications. Forty-eight percent (48%) of the teachers sampled in that study did not have the qualifications to teach mathematics, but 78% of the teachers sampled believed their qualifications were adequate (Riordain & Hannigan, 2011). However, accumulating hours of experience of doing the same thing over and over does not necessarily lead to improvement. In fact, things may stay the same or get worse (Ericsson & Poole, 2016).

School principals are aware of the effects of out-of-field teaching on student achievement as evidenced by the fact that they tend to assign teachers, who are not qualified and who are less experienced, to teach fewer mathematics courses, which are lower-level and not exam-based (Riordain & Hannigan, 2011). There is a distinct difference between expert teachers and experienced teachers in how they organize the content knowledge in their minds and how they teach the content (Hattie, 2012; National Research Council, 2000). Teacher qualifications matter, but teachers without a formal background in mathematics self-assessed their qualifications to be adequate to teach the subject matter (Riordain & Hannigan, 2011). Out-of-field teachers need to gain both subject matter knowledge and teaching experience to build their teaching expertise. They cannot “gain expertise from experience alone” (Ericsson & Poole, 2016, p. 133).
2.3. Stages of Self-Directed Learning

Self-directed learning is:

a process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes. (Knowles, 1975, p. 18)

Self-directed learners can identify their deficiencies, find ways to remedy those deficiencies, manage their time effectively, critically self-assess understandings, and undertake other opportunities for learning (Knowles, 1975). NMSSTs are self-directed learners. They are expected to initiate their professional learning, plan and manage their own learning, assume primary responsibility for their own learning, take control of their learning, and characteristically be autonomous (Caffarella, 1993).

Self-directed learning does not mean learning in isolation (Knowles, 1975). Self-directed learning is autonomous in nature, but expertise and guidance from others is also needed (National Research Council, 2000). “People move toward self-directedness at differing rates” (Caffarella, 1993, p. 30). Self-directed learning for NMSSTs means choosing to engage in professional learning. There is also a level of autonomy within that learning activity. Factors influencing the level of self-directedness within the learning activity are self-perceived technical skill level, familiarity with the subject matter, sense of personal competence, and context of the learning event (Caffarella, 1993). Self-directed learning is situational (Grow, 1991). It depends on the level of support and guidance NMSSTs believe they require to gain the subject matter knowledge in mathematics.

Grow (1991) categorizes self-directed learning into four stages: highly dependent, moderately self-directed, intermediately self-directed, and self-directed. These four stages create the framework for this study in terms of types of professional learning, which describes the level of self-directedness of each learning activity to be discussed later in the study. Each stage of Grow’s categorization described below depicts NMSSTs as the learners and subject matter experts as the teacher.
2.3.1.  **Stage 1: Dependent learners**

At Stage 1, NMSSTs are dependent learners who “need an authority figure to give them explicit directions on what to do, and when” (Grow, 1991, p. 129). The teacher is the expert and the learning environment is teacher-centered with little self-direction on part of the learner. The teacher makes the students learn (Grow, 1991). Learners respond to “a clearly-organized, rigorous approach to the subject” (p. 130) with definitive deadlines for assignments and clear instruction. The learner requires continuous teacher direction and immediate feedback. Learning is primarily focused on the subject matter and communication is 1-way (Grow, 1991). Instruction consists of informational lectures and “grading must be unequivocal, objective, and cleanly related to the task at hand” (p. 130). University programs where coursework is evaluated, learning outcomes prescribed, and direct instruction is implemented best reflect the didactic nature of this stage.

Graduate programs, undergraduate programs, diploma or certificate programs, and university mathematics courses are formal professional learning activities considered in this study. NMSSTs participating in these learning activities earn credits and credentials when they successfully complete the course or program. Teachers as learners who obtain a graduate degree or diploma in mathematics or mathematics education acquire mathematics as a subject speciality and a new teaching category at the Teacher Qualification Service (TQS, 2016). They may also receive increased pay.

2.3.2.  **Stage 2: Moderately self-directed learners**

At Stage 2, NMSSTs are moderately self-directed learners. The teacher is an inspirational lecturer who effectively leads discussions. Additionally, the learner is willing to participate with teacher direction (Grow, 1991). The teacher tends to be motivating, enthusiastic, and excited about what he or she is teaching, and the learner is equally excited about the content (Grow, 1991). The teacher sets high standards, motivating learners to achieve them with encouraging feedback and close supervision; the learners are “good students” (p. 131) and equally motivated to meet those expectations (Grow, 1991). The communication between the teacher and student is 2-way (Grow, 1991). The
professional learning activities that best reflect this stage of self-directedness are professional development days, conferences, and in-service workshops.

Provincial conferences, professional development days, in-service workshops, and continuing education are traditional professional development learning activities considered in this study. These learning activities take “a structured approach to professional development that occurs outside of the teacher’s classroom” (Garet et al., 2001, p. 920). Experts in the field are likely to facilitate the learning in these learning activities, which participants attend at a specific time and place. Course credits are not awarded. These learning activities are relatively affordable and typically designed to meet the learning needs of teachers as learners who choose to attend.

2.3.3. Stage 3: Intermediate self-directed learners

At Stage 3, NMSSTs are intermediate self-directed learners. “They have skills and knowledge, and they see themselves as participants of their own education” (Grow, 1991, p. 133). These learners are more willing to explore independently to develop a deeper self-concept, confidence, and sense of direction (Grow, 1991). They also benefit from learning more about their own learning (Grow, 1991). The learners see themselves as equals with the teacher (Grow, 1991). They seek out opportunities to work with the teacher to develop their critical thinking and co-create their learning experiences (Grow, 1991). Learners at this stage work well with others and share in the decision-making with the teacher. Learning is more problem-centered, not subject-centered (Merriam, 2001; Chesbro & Davis, 2002). Professional learning activities that best reflect this stage of self-direction are learning communities, reading groups, or social media use.

School- or district-based learning communities, reading or study groups, and social media or Listservs are communities for professional learning considered in this study. NMSSTs work collaboratively with like-minded people to achieve a common goal. Learning communities provide NMSSTs with opportunities to work with subject specialists, department heads, and school principals as equals to acquire additional subject matter content knowledge in mathematics. The student-teacher relationship is mutual and reciprocated (Grow, 1991). NMSSTs are both learners and teachers; likewise, the expert in the field engages as teacher and learner.
In Wenger’s (1998) community of practice, a learning community is described as a “group of individuals who, through the pursuit of a joint enterprise, have developed shared practices, historical and social resources, and common perspectives” (Coburn & Stein, 2006, p. 28). The participants form a community with a mutual desire to develop and strengthen their mathematics content knowledge. “Learning is conceptualized as the way in which communities gradually transform their practices through ongoing negotiation of meaning as they engage with one another” (p. 29). Communities of practice are found in schools, districts, and online. NMSSTs acculturate into teaching mathematics and gain subject matter knowledge by engaging with peers and participating in the routines and rituals of the community (Coburn & Stein, 2006).

Another type of learning community is a professional learning community (PLC), which is composed of “teachers and administrators [who] seek and share ways to improve their teaching practice and the learning of their students” (Kornelis, n.d., para. 2). Much like the communities of practice, PLCs have shared understandings and values, have a collective inquiry, and require collaborative teamwork (Kornelis, n.d.). PLCs are action oriented, committed to continuous improvement, and focused on improved student achievement (Du Four & Eaker, 1998). PLCs have a culture of collaboration and are evidence-based where indicators of progress are measurable (Du Four, 2004).

Learning communities as professional learning involve active learning, reflection, and social interaction to construct knowledge through exposure to multiple perspectives (Hord, 2009). “Norms of collegiality, collaboration, and experimentation… in which teachers learned continuously” (Loucks-Horsley, Matsumoto, 1999, p. 265) are established within a learning community. Collective participation allows teachers to work together, discuss problems, and share materials over time to sustain change in a culture of learning and shared understandings (Garet et al., 2001). “Sense-making is not a solo affair” (Spillane et al., 2006, p. 56). Learning communities have learners belonging to a group, working with peers, and sharing a common goal.
2.3.4. Stage 4: Self-directed learners

At Stage 4, NMSSTs are self-directed learners where they “set their own goals and standards with or without help from experts” (Grow, 1991, p. 134). These learners are motivated by internal, not external, factors (Chesbro & Davis, 2002; Merriam, 2001) because they understand what they must learn and why (Chesbro & Davis, 2002). Self-directed learners are independent, but they do not learn alone (Solomon, 2003). These learners consult with the teacher as mentor to help them to achieve their goals, if needed (Grow, 1991). They take full responsibility for their own learning, direction, and productivity; they manage time appropriately, self-evaluate, and peer-assess (Grow, 1991). The teacher as mentor steps away from a 2-way communication and external reinforcement to focus more on a supportive relationship with the learner (Grow, 1991). “The instructor becomes less important to the personal learning of the student as the educational process continues” (Forrest & Peterson, 2006, p. 116). The role of the teacher is to encourage, empower, and consult with the learner and shift the focus from subject matter to the learner (Grow, 1991). Self-directed learners desire to learn on their own terms (Grow, 1991). They are autonomous. The professional learning activities that best reflect this stage are online resources, mathematics textbooks, and teaching.

Learning the subject matter from the act of teaching, mathematics textbooks, books about mathematics, and online resources are autodidactic professional learning activities considered in this study. Autodidacts are self-taught and resent the narrow learning conditions of formal instruction (Solomon, 2003). Autodidacts have a strong desire to learn, but by their own rules (Solomon, 2003). They “engage in [professional learning] through [their] own actions and motivation rather than as receivers of learning specified and provided for [them] by others” (Edwards, 2003, p. 73). Autodidacts have “a great wish to learn for and by themselves” (Solomon, 2003, p. 4). However, they may work with a mentor for guidance or help (Solomon, 2003). Self-directed NMSSTs are likely to learn the subject matter independently with or without the support of a mentor.

Self-directed NMSSTs can strengthen their mathematics content knowledge by doing mathematics (Loucks-Horsley & Matsumoto, 1999). They “pick up knowledge from non-teaching situations, in one way or another” (Solomon, 2003, pp. 3-4). NMSSTs can learn from teaching mathematics, preparing for a mathematics class, or from a student in
class. Autodidactic learning activities provide NMSSTs with flexibility and autonomy, which are accessible and affordable. Another opportunity to gain subject matter content knowledge for NMSSTs is the Internet. “Technology is increasing in its use for professional learning” (Loucks-Horsley & Matsumoto, 1999, p. 264). NMSSTs can go to Khan Academy, an online webinar, or YouTube to learn the content.

Mentoring may be formal or informal. The school or school district may have a mentoring program in place to ensure new teachers and teachers new to teaching a subject area or grade are provided with a mentor. This is formal. Otherwise, working with a colleague without the support of a school or school district mentoring program is considered informal. In this study, however, mentoring was classified as a learning community instead of an autodidactic learning activity because those who participated in the pilot test better understood the term to be working with someone in a learning community. Likewise, autodidactic learning activities were understood to mean self-taught or learning independently. Therefore, Stage 4 learning activities are ones that can be achieved by working alone with the possible support of a mentor. Working with a mentor or colleague was re-categorized as a learning community learning activity.

2.4. Conceptual Framework

There are four types of professional learning identified in this study based on Grow’s (1991) four stages of self-directed learning: (a) formal professional learning activities, (b) traditional professional development, (c) learning communities as professional learning, and (d) autodidactic professional learning activities (Figure 2.1). Sixteen professional learning activities were considered in this study with four learning activities categorized into each type (see Chapter 4, Section 4.1.2).
Figure 2.1. Types of professional learning activities.

2.5. Summary

NMSSTs are likely to participate in professional learning to strengthen their mathematics content knowledge to teach secondary mathematics in BC schools. Professional development for teachers takes on many forms. Many teachers attend traditional professional development like workshops and conferences, which are short-term, one-time sessions held off-site from where teachers teach. On the other hand, non-traditional professional development such as mentoring or study groups is ongoing, onsite opportunities for teachers to collaborate with the support and guidance of an expert in the field. In the literature, junior mathematics teachers in Australia strengthened their mathematics content knowledge through intensive coursework after school, mentoring, and in-class assignments. Chinese teachers developed a profound understanding of fundamental mathematics by studying the teaching materials intensely, teaching each grade from Kindergarten to Grade 7 (K-7) over a period of years, and learning with peers in research groups. Teachers, mathematicians, and college educators can also collaborate to provide certificate programs or short courses in mathematics for teachers or to educate teacher leaders and school administrators to
improve their understanding of the subject matter. They can also hire mathematics facilitators to support other teachers in schools.

NMSSTs are likely to engage in some professional learning on the job to learn or to relearn the subject matter to teach secondary mathematics as out-of-field teachers. Learning on the job involves experiential learning. The experiential learning cycle begins with a concrete experience and then moves onto reflection, reconceptualization, and experimentation. NMSSTs engage in this learning cycle to identify what subject matter needs to be learned or relearned and to find ways to acquire that knowledge. In this way, NMSSTs develop teaching expertise and expertise with the subject matter. Teaching expertise develops over time starting from novice and moving on to advanced beginner, competent performer, proficient performer, and expert (Berliner, 2004). Novice teachers are relatively inflexible, algorithmic, and rule-driven, whereas expert teachers are more fluid and holistic in their approach. Expert teachers, when compared to experienced teachers, have the same amount of content knowledge, but expert teachers can organize the content so that they uncover meaningful patterns that are relevant and applied beyond the knowledge of facts. Experienced teachers have a surface-level understanding of the subject matter while expert teachers demonstrate a deeper level of understanding.

Teachers in BC are encouraged to be self-directed learners, to self-identify any learning gaps they may have and determine what professional development would be best to bridge those gaps. NMSSTs demonstrate different levels of self-directedness in learning the subject matter. Based on Grow’s (1991) four stages of self-directedness, four types of professional learning activities were identified. At the first stage, learners are dependent. They prefer clear direction and instruction from an expert in the field. These learners participate in formal learning activities such as attending university. At the second stage, learners are moderately self-directed and communication with the teacher is 2-way. These learners participate in traditional professional learning activities such as workshops and conferences. At the third stage, learners are intermediate self-directed, and they co-create their learning experiences with the teacher. These learners participate in learning communities as professional learning. At the fourth stage, learners are self-directed and prefer to be independent and autonomous learners. These learners participate in autodidactic learning activities. They are self-taught and learn by their own
rules away from the classroom environment. They would rather learn the subject matter from textbooks or go online. They may ask for support from an expert.

Gaining subject matter content knowledge involves time, deliberate practice, and reflection to develop a deep understanding and expertise with the help from an expert in the field. Out-of-field teachers can participate in a wide variety of professional learning activities to strengthen their mathematics content knowledge based on what is accessible, what is available, and the level of self-direction. High quality professional development is ongoing, onsite, and collaborative, yet many teachers participate in traditional professional development that may be disconnected or separate from their practice. Out-of-field teachers must self-assess and self-identify their professional learning needs as self-directed learners. In turn, they need to find and participate in professional learning activities to bridge those gaps. Which professional learning activities NMSSTs participated in to gain subject matter knowledge as practicing secondary mathematics teachers in BC schools are identified in Chapter 4: Data Analysis. The data collection process is described in Chapter 3: Design of the Study.
Chapter 3. Design of the Study

In this quantitative descriptive research study, survey design was implemented via an online questionnaire to collect data and generate descriptive statistics to identify what professional learning activities non-mathematics subject specialist teachers (NMSST) participate in to gain subject matter content knowledge in mathematics as practicing secondary mathematics teachers in British Columbia (BC) schools. The online survey questionnaire also acquired information to describe NMSSTs participating in this study. It determined which learning activities NMSSTs used most frequently, perceived to be most valuable, believed best facilitated the acquisition of the subject matter content knowledge, and deemed helpful in teaching secondary mathematics better. This chapter describes the methodology of the study including participant selection, instrumentation, pilot tests, data collection procedures, data analysis plan, and ethical considerations.

3.1. Research Design

“Descriptive research examines a situation as it is” (Leedy & Ormord, 2010, p. 182). It looks at “what is” by collecting information to define characteristics, attitudes, and behaviour without changing the environment (Leedy & Ormord, 2010). The study was not experimental (Creswell, 2009; Leedy & Ormord, 2010). It is a cross-sectional study where data was collected at one point in time to capture the situation, as it existed (Creswell, 2009; Leedy & Ormord, 2010). This study collected information on the professional learning activities NMSSTs participated in to gain subject matter knowledge in mathematics and background information of participants by using an online survey.

“Survey design provides a quantitative or numeric description of trends, attitudes, or opinions of a population by studying a sample of that population” (Creswell, 2009, p. 145). The online survey questionnaire gathered quantitative data mainly through closed-
ended questions and a few short-answer responses. Open-ended questions labelled “Other” allowed for any additional information about the participant’s professional learning experience. Sixteen professional learning activities were considered in this study. Trends, correlations, and points of interest were summarized in the data analysis.

3.2. Setting

The population is NMSSTs who are currently teaching or have taught secondary mathematics in BC schools. These teachers have taught at least one class of secondary mathematics and participated in professional learning to gain subject matter knowledge. NMSSTs would be considered a “hard-to-reach” (Baltar & Brunet, 2012, p. 57) population. These teachers are “not easy to detect” (p. 61) because their credentials or subject specialities are not administratively visible in government statistics, therefore making a sampling frame impossible (Baltar & Brunet, 2012). As a result, to access this hard-to-reach or hidden population over a large geography (i.e., the province of BC) and with limited time, budget, and manpower, I decided to implement an online survey questionnaire with an online recruiting strategy for participants (Baltar & Brunet, 2012). Invitation to participate, participation, and data collection were administered online using email, personal social media accounts, and Survey Monkey. Information about the study was also made available at my website at: www.christineyounghusband.com/research.

Initially, I made contact with potential participants and those who may know of potential participants from my professional learning network (PLN). Members of my PLN are educators who may be currently practicing NMSSTs, former NMSSTs, or those in the field who may know of teachers who are or were NMSSTs. Using non-probability, purposeful sampling (Creswell, 2012; Baltar & Brunet, 2012), I contacted people by email or messaging via my personal Facebook or Twitter account. I did not ask members of my PLN for names or contact information of potential participants they recommend for this study nor did I hire or pay a company to recruit participants for this study. Members of my PLN were asked to participate in the study or forward the invitation on to members of their PLN who might be viable candidates for this study. These individuals were asked to do the same, thus enacting a voluntary chain referral sampling process (Baltar & Brunet, 2012). Furthermore, the link to my personal website where the invitation to
participate was located was tweeted and posted to my personal Twitter and Facebook accounts. Those who were tagged in the tweet or post, Twitter followers, or Facebook friends could have participated in the study or retweeted or reposted the invitation to participate to their social media networks.

The letter of invitation, with a link to the online survey, was also posted in the BC Association of Mathematics Teachers (BCAMT) Listserv. The BCAMT is a provincial specialists’ teachers’ association of the BC Federation of Teachers, and members of the Listserv are self-subscribed. The BCAMT secretary and BCAMT president moderate the email Listserv. Members of the Listserv can post emails of inquiry, information for sharing, or requests on the Listserv. I am a member of the BCAMT Listserv and was a member of the BCAMT Executive Committee during the data-collection period of this study. As a member of the Listserv, I posted the letter of invitation (Appendix A) onto the Listserv that is moderated by the BCAMT. Permission to distribute the letter of invitation on the Listserv was not required because the BCAMT had approved other invitations for educational research. However, I did seek informal approval via email from the Listserv moderators to post a letter of invitation for this study. As a Listserv member, I do not have access to the BCAMT Listserv contact list. The Listserv membership is self-subscribing, and membership of the Listserv generally fluctuates.

Potential participants who accessed or received a letter of invitation via email or social media were reminded that email and direct messaging were not confidential mediums of communication. This virtual snowball-like sampling procedure entailed a non-probability sampling method with the initial contact and qualities of probability sampling when the invitation was retweeted, reposted, or forwarded to other people. Contact information was not collected throughout the 2-week data collection period. Participants of the study and invitations to individuals to participate beyond the initial request were anonymous. Moreover, participants for this study were not recruited or obtained from any official contact list, including the BCAMT Listserv. This was a voluntary chain referral process (Baltar & Brunet, 2012). The data collected was not generalizable because of the non-probability sampling methods used, but likely more representative of the target population because using a virtual online referral method using social media, email, and a Listserv were more effective than traditional sampling methods to recruit participants from a “hidden population” (Baltar & Brunet, 2012, p. 58).
The letter of invitation encouraged potential participants to complete the online survey questionnaire or forward the letter to colleagues who satisfied the NMSST participant profile. The participant profile was written in the invitation to participate, which stated that viable participants must be currently teaching or must have taught secondary mathematics in BC schools, must not have completed a degree in mathematics or one with significant content prior to teaching secondary mathematics, and must have participated in professional learning to gain subject matter knowledge in mathematics. Participants had to self-identify as non-mathematics subject specialists to participate in the study. Self-identification also made this target population “hard to reach” (Baltar & Brunet, 2012, p. 58). Participants accessed the online survey questionnaire with a link that was embedded in the letter of invitation. The online survey questionnaire was created on Survey Monkey, which meant that data was collected on a server outside of Canada. Participants were informed on the online survey questionnaire about the U.S. Patriot Act and were told that the United States authorities, without notification, could access the data they provided. The appropriate disclaimer was included in the informed-consent section of the survey.

Survey Monkey was used to create this online survey questionnaire because the SFU Web Survey Tool, the survey software available at the time, was inadequate to facilitate the type of questioning needed for this study. There were no comparable Canadian online-survey options available at the time. After the 2-week data collection process was complete, data was imported and secured in Canada in both a PDF file and an Excel file and stored on a password-protected computer.

3.3. Population Sample

Participants were required to be 19 years and older. They were asked to self-identify as NMSSTs and indicate that they had participated in at least one professional learning activity to proceed with the online questionnaire.

The population of NMSSTs in BC schools is currently unknown. Although some data exists as evidence that out-of-field teaching in secondary mathematics exists in BC schools (BCCT, 2001, 2004), there is no data currently available that indicates teacher
job assignments, educational background of individual teachers, or subject specialization of teachers. NMSSTs are a hard-to-reach population or hidden population (Baltar & Brunet, 2012). When teachers are certified to teach in BC with a professional certificate, there is no restriction on the grade level or subject area these teachers can teach, unlike subject-restricted certificates that are issued within independent schools (BC Ministry of Education, 2017a). Subject-restricted certificate teachers have a formal background in a particular subject area but have not completed formal training in a teacher-education program (BC Ministry of Education, 2017b). NMSSTs in this study were certified teachers possessing a professional certificate, assigned to teach secondary mathematics out-of-field within BC schools.

3.3.1. Sample size

There are no statistics on out-of-field teaching kept in BC, so there is no way to determine the size of the population from which I am sampling. In this study, 73 participants self-identified as NMSSTs and 62 completed the survey questionnaire in full. This sample does not represent the population of NMSSTs, thus the data collected describes the learning experiences of only the NMSSTs participating in this study.

3.3.2. Sampling methods

In BC schools, collective agreements in public schools and the Independent School Teacher Conduct and Competence Standards established by the BC Ministry of Education (2016c) provide policy language regarding teacher assignments. Teaching assignments are site-based decisions made by principals annually. Teaching assignments are based on factors such as a teacher’s professional training, qualifications, teaching experience, and personal preference. It is expected that “educators understand the curricular, conceptual and methodological foundations of the subject areas they teach” (Item “6. Educators have broad knowledge”). With these parameters, teachers may be assigned within a school to teach secondary mathematics out-of-field without a strong consideration of the teachers’ subject matter preparation.

Before proceeding with the online survey questionnaire, participants needed to satisfy the NMSST participant profile: (a) currently teaching or have taught in BC
schools, (b) currently teaching or have taught secondary mathematics in BC schools, (c) did not complete a degree in mathematics or one with significant mathematics content prior to teaching secondary mathematics in BC schools, and (d) participated in at least one professional learning activity to gain subject matter content knowledge in mathematics during their teaching practice as secondary mathematics teachers. Not knowing the number of NMSSTs in BC, and given the limitations of the study, I implemented an online chain referral sampling process where initial contact was purposefully selected from my PLN, and then distribution of the invitation to participate and participant recruitment were achieved using social media, email, and a Listserv (Baltar & Brunet, 2012; Creswell, 2012). Individuals were encouraged to participate or forward the letter of invitation to teachers in their PLN who may satisfy the participant profile.

Purposeful sampling entailed sending the letter of invitation by email or link to my website via my personal Twitter and Facebook accounts to colleagues in my PLN who may have satisfied the NMSST participant profile or may have known of teachers who may have satisfied the NMSST participant profile. Email addresses and social media contacts used were from my PLN. The letter of invitation included a brief description of the study, participant profile, conditions for participation, and a link to the online survey questionnaire. All recipients of the invitation were encouraged to complete the survey if they satisfied the NMSST participant profile. They were also encouraged to forward the invitation to members of their PLN who may have satisfied the participant profile.

I posted the letter of invitation electronically on the BCAMT Listserv, a self-subscribing email service for interested mathematics educators. BCAMT-Listserv participants include mathematics educators from public schools, independent schools, and universities or colleges. Participation in the BCAMT Listserv is voluntary. There are approximately 930 users. The electronic invitation to this study was not exclusive to members of the BCAMT Listserv. Participants acquired did not represent the BCAMT or any other organization they are affiliated to. A link to the letter of invitation was also available on my website at www.christineyounghusband.com/research. The online sampling process to participate in this study occurred over a 2-week period.
Originally, I anticipated a second round of sampling if there were not enough participants. After 2 weeks, 73 participants proceeded with the online survey questionnaire, and 62 completed the survey in full. In the end, I decided not to undergo a second round of sampling because it was apparent after the first 10 days of the sampling that all sampling resources were maximized. I received several confirmations of completion and other emails, tweets, or direct messages indicating that there was an oversaturation of online requests during the first 2 weeks. Given that there were no incentives or rewards for participating and that this study describes the NMSST participants acquired, I was satisfied with the number of participants and data collected.

The sample population was limited to those who were aware of the study by word-of-mouth, email, BCAMT Listserv, website access, and social media during the 2-week data-collection period. Participants were recruited from around the province with no particular institution or organization being sampled from. Prior to participation, potential candidates were fully informed of the intent of the study, procedures, confidentiality, and my contact information in case of any questions. The online distribution of the letter of invitation and anonymous participant recruitment were as follows: four emails on the BCAMT Listserv, eight direct messages on Twitter, three Facebook posts with tags of individuals in my PLN, 35 Facebook shares, 15 Facebook comments, two Facebook messages, 10 days of multiple tweets with hashtags and mentions with a link to the letter of invitation, 66 Twitter retweets, 13 Twitter mentions, 24 Twitter mention retweets, 28 Twitter likes, and 36 email invitations to those within my PLN.

Participation in this study was voluntary. The disclaimer for participating in a survey through Survey Monkey was provided in the online survey questionnaire prior to Questions 1 and 2, the consent to participate. Failure to give consent or failure to satisfy the NMSST participant profile in Questions 3 to 5 and 7 took respondents out of the online survey questionnaire. Participants also had the freedom to withdraw from the study at any time before their data had been submitted. To withdraw from the survey, participants closed the browser window before hitting the submit button. However, participants could not withdraw from the study after the data was submitted because participation was anonymous and data could not be identified and removed. The data
was coded, and the survey questionnaire was set not to collect IP addresses or email addresses. Anonymity in this study is described further in sections below.

### 3.4. Instrumentation

I developed an online survey questionnaire titled “The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study” on Survey Monkey. A disclaimer statement was made on the survey questionnaire regarding the use of Survey Monkey and the U.S. Patriot Act prior to informed consent. The survey took approximately 5 to 20 minutes to complete. The data collected on Survey Monkey was exported and analyzed on Excel. The online survey questionnaire was composed of closed-ended questions and short answer responses. Closed-ended questions included yes/no, multiple choice, and Likert Scale questions. Short answer responses included 1-line fields and a response of “Other” at the end of each section.

The survey began with informed consent and questions regarding the NMSST participant profile. If participants declined consent in Questions 1 and 2 or did not satisfy the four questions relating to the NMSST participant profile in Questions 3, 4, 5, and 7, participants were exited from the survey. Otherwise, participants continued with the online survey questionnaire. Professional learning activities were sub-divided into four types based on Grow’s (1991) four stages of self-directed learning: autodidactic, learning communities, traditional professional development, and formal learning. The level of self-directedness for NMSSTs was determined in terms of frequency of use and value.

Following informed consent and the NMSST participant profile, the next four sections of the online survey questionnaire reflected the four types of professional learning with four specific professional learning activities representing each type, resulting in 16 professional learning activities. If the participant answered “yes” to participating in an activity, two sub-questions followed the question: the first asked to what extent the activity strengthened his or her knowledge of mathematics and the second asked to what extent the activity helped him or her to teach secondary mathematics better. A 4-point Likert Scale was used with each sub-question ranging from “to a great extent” to “not at all.” A 4-point scale was used to force participants to
make a choice with no neutral option provided (Garland, 1991). If the participant answered “no”, the survey proceeded to the next learning activity. At the end of each section, an option of “Other” was provided in case the participant wanted to give a short response on any other professional learning activities he or she participated in.

The survey concluded with participants ranking their top three most valuable professional learning activities. Following this ranking process, questions about the participant's background information such as age group, gender, and years of experience were asked to provide some insight on those participating in this study. These questions were closed-ended. Other questions about the participant asked them to self-assess their perceived level of subject content matter knowledge in mathematics, perceived level of expertise in teaching secondary mathematics, and whether he or she self-identified as a secondary mathematics specialist teacher. The perceived levels of subject matter knowledge and expertise was based on a 5-point Likert Scale with descriptors retrieved from Berliner’s (2004) stages of expertise: novice, advanced beginner, competent performer, proficient performer, and expert. Self-identifying as a secondary mathematics subject specialist teacher was a “yes” or “no” question.

3.5. Pilot Test

The online survey questionnaire underwent pilot testing in two stages, the first stage with members from the BCAMT Executive Committee and the second stage with NMSSTs purposefully identified from my PLN.

An email request was sent to the 2015-2016 BCAMT Executive Committee in June 2015 via “BCAMT-exec group” email. There were 21 committee members and seven responded. Five completed the pilot test. The BCAMT-pilot participants acted as an expert panel to review the survey to provide face validity and formative feedback on how the survey could be improved in the areas of clarity, appropriateness, flow, and non-bias. Upon agreeing, the BCAMT-pilot participants received an invitation email (Appendix B) to participate in the first stage. In this email, a PDF of the draft survey questionnaire was provided in addition to a feedback form as a Word document (Appendix C).
The BCAMT-pilot participants were asked to complete the survey as if they were NMSSTs. They were also asked to make note of how long it took to complete the survey and to fill in and return the feedback form to me by email. I accepted other informal comments regarding the survey as feedback. The BCAMT-pilot participants were also asked to provide a phone number to me in case any clarification was needed.

Revisions to the first draft of the online survey questionnaire were made based on the feedback provided. Major changes included changing the language of the introduction, clarifying distinct sections within the survey with titles, and defining or re-defining key terms. The overall structure of the survey questionnaire remained unchanged. The intent of the suggested changes was to make the survey questionnaire more user-friendly by implementing simpler language and visual prompts to guide the participant. Once these revisions were completed, I contacted 10 NMSSTs identified from my PLN in July 2015 via email, Twitter direct message, and Facebook messenger to participate in the second stage of the pilot test. Eight responded. The email invitation (Appendix D), survey link, PDF of the newly drafted online survey questionnaire, and feedback form (Appendix C) were sent to these NMSST-pilot participants. All eight NMSST-pilot participants completed the survey and six returned the feedback form. More revisions were made to the survey questionnaire.

Both BCAMT- and NMSST-pilot participants took the second pilot test. The BCAMT-pilot participants confirmed that the appropriate changes were made based on initial feedback. NMSST-pilot participants were testing the consistency of the survey questionnaire responses when compared to the first pilot test (see Section 3.6). The NMSST-pilot participants also provided feedback on the same four areas of clarity, appropriateness, flow, and non-bias, as did the BCAMT-pilot participants.

The second set of revisions included changing age groups and years of teaching experience to 5-year intervals, moving “teacher mentorship” from autodidactic to learning communities, and restructuring Question 71 so any particular professional learning activity could not be identified and repeated as the first, second, and third most preferred professional learning activity. Several pilot participants believed that mentoring was more like a learning community (e.g., learning with others) than autodidactic learning (e.g., self-taught). Other changes included removing “Other” as an option for gender,
deleting “mathematics department meetings” as a learning activity option, and removing the asterisk from required questions. Changes made to the online survey questionnaire were minor. A third phase of the pilot test was not implemented.

The second phase of the pilot test occurred during the summer months, and not all pilot participants responded to the initial request. Two BCAMT-pilot participants and one NMSST responded late to the invitation email. At this point, the survey questionnaire was almost finalized. These pilot participants were asked to complete the survey and give some comments on the final draft in August of 2015. Feedback provided from this unofficial third stage of pilot testing suggested some cosmetic changes like using bold font, removing numbers to questions, and changing tenses. No major changes were requested. Cosmetic changes were not implemented. All feedback in all pilot tests was taken into consideration, but not all suggestions were incorporated.

I completed the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans Course on Research Ethics (see Appendix E) online prior to submitting the PDF of the final survey instrument and study details to the Simon Fraser University Office of Research Ethics. Recommendations were made, and minor revisions were conducted on the survey questionnaire, which included adding the supervisor’s name and contact information, listing the potential benefits and risks of the study, and the extent of the dissemination of results. With these revisions, the survey instrument and study details were approved. Distribution of the letter of invitation, request for participation, and data collection proceeded soon after ethics approval.

### 3.6. Reliability and Validity

The reliability and validity of the survey instrument was established with the pilot tests prior to SFU ethics approval. “Reliability means that scores from an instrument are stable and consistent” (Creswell, 2012, p. 159). When is “the respondent’s answers correctly indicate what the question is set out to measure” (Berends & Zottola, 2009, p. 84), the question is valid. The more reliable the survey instrument is, the more valid the data collected will be (Creswell, 2012). I implemented two stages of the pilot test. The first stage of the pilot test included five BCAMT Executive Committee members to
provide feedback and face validity. Face validity is achieved when experts are asked to scrutinize the survey instrument and provide constructive feedback on the apparent validity of the instrument (valid on its face) (Leedy & Ormord, 2010). In other words, answering the question: in the opinion of experts in the field, does the survey look like it is correctly gathering the desired data? This was followed up by a second stage with eight NMSSTs who satisfied the NMSST participant profile from my PLN. They participated in the survey and provided feedback to ensure the reliability of the survey questionnaire.

The pilot concluded with three participants from the first and second stage of the pilot tests participating in the final draft of the survey, which resulted in no major revisions. This provided an opportunity to visually check individual responses for internal consistency, that is, the reliability of the survey instrument (Creswell, 2012; Leedy & Ormrod, 2010). The sample sizes were too small to determine statistical reliability in this study. In the second stage of the pilot test, BCAMT-pilot participants completed a second version of the survey instrument, which was noticeably revised from the first stage of the pilot test. However, similar results were produced by BCAMT-pilot participants from questions that remained the same in the survey instrument from both stages of the pilot test. Consistency improved by standardizing how the online survey was distributed, collected, and explained to participants. Data collected from both pilot tests were not included in the data analysis of the actual study (Creswell, 2012), though some of the data collected from the pilot tests were used to develop the data analysis plan.

### 3.7. Data Analysis Plan

The data collected were analysed using descriptive statistics, which indicated central tendencies, variability, correlations, and ranking order (Creswell, 2012; Leedy & Ormrod, 2010). The data analysis plan was devised from data acquired from the second stage of the pilot test, where the draft-survey questionnaire resembled the final draft of the questionnaire used in the study. Information from 10 pilot participants, from both the BCAMT and NMSSTs, were used to test this data analysis plan. Data analysis was performed on Excel. Nominal, ordinal, and interval data were coded numerically to
conduct the analysis. A summary of responses for each question found on Survey Monkey under “analyze results” were also noted in the results.

Referring to the PDF of the final draft of the survey questionnaire in Appendix F, Questions 1 and 2 were required questions to establish informed consent. “Yes” to both questions was needed to proceed with the survey questionnaire. Questions 1 and 2 did not require any data analysis. Questions 3 to 5 and 7 were also required questions. These questions ensured that participants satisfied the NMSST participant profile (e.g., were currently teaching or had taught secondary mathematics in BC schools, did not complete a mathematics degree or mathematics-related degree prior to teaching, and participated in professional learning). Answering these questions inappropriately resulted in a disqualification, and participants did not proceed to the survey questionnaire. If participants answered “yes” in Question 5 (e.g., did you complete a mathematics or mathematics-related degree prior or teaching), they were directed to Question 8. In Question 8, participants were asked which mathematics or mathematics-related degree they completed prior to teaching in BC schools before exiting the survey. No analysis was conducted for Questions 3 to 5 and 7. Concluding Section 1 of the survey was Question 6, asking the importance of participating in professional learning for NMSSTs.

Responses from Question 6 and Background Information questions were used to describe NMSSTs participating in this study as “NMSST characteristics.” These were identified using the median and mode. Questions 73 and 75 asked the age group and years of experience in 5-year intervals. Circle graphs were used to summarize this data. Nominal data generated from Questions 74, 76, and 78, indicating the participant’s gender, place of work, and self-identifying as a mathematics subject specialist. A frequency table was used to depict where participants taught mathematics (Question 76) in BC schools (e.g., public, independent, private, First Nations, or other) and a Chi-Square Test was used to determine which factors significantly influence NMSSTs in this study to self-identify as mathematics subject specialists.

Questions 77, 79, and 80 used Likert scales to determine how much of the participant’s teaching assignment was committed to teaching secondary mathematics, the perceived level of teaching expertise as a secondary mathematics teacher, and the perceived level of subject matter content knowledge in mathematics. The median and
mode summarized this data. Potential correlations between six NMSST characteristics (e.g., age group, years of experience, teaching assignment, perceived level of subject matter, perceived level of expertise, and the importance of professional learning for NMSSTs) were determined using Spearman’s Rank Correlation Coefficient and Rho-Critical values at $\alpha = .05$.

In Sections 2 to 5, a tally determined which type of professional learning the participants most frequently used (e.g., autodidactic, learning communities, traditional professional development, and formal learning) and was summarized on a histogram. A similar tally was kept for the 16 individual professional learning activities and summarized on a frequency table. If the participant answered, “yes” to participating in a particular professional learning activity, there were two follow-up questions about that activity. Median, mode, and percent of respondents choosing “a great extent” on the Likert scale, were listed in descending order. A correlation between the two sub-questions of the study, SQ1 (facilitating the acquisition of subject matter) and SQ2 (helping to teach mathematics better), was calculated for significance using Spearman Rank Correlation Coefficient and Rho-Critical values at $\alpha = .05$. A further analysis was conducted to look for any significant correlations between SQ1, SQ2, and perceived level of subject matter content knowledge and level of teaching expertise.

Question 71 asked participants to identify the top three professional learning activities they believed were most valuable in gaining mathematics content knowledge. The activity deemed most valuable was worth 3, second most valuable 2, and third most valuable 1. Responses were ranked in descending order based on weighted sums and percent of participants selecting that particular learning activity as one of their top three most valuable learning activities. A further analysis was conducted on two sub-cohorts of participants based on the learning activity participated in to compare which professional learning activities these participants believed were most valuable compared to the entire sample. Additional data analysis may be conducted based on any unexpected trends identified. The final analysis involved summarizing short answers provided, “Other” responses, and final comments in separate qualitative analyses where key terms were coded in each type of question to establish common themes, trends, and patterns.
3.8. Potential Benefits

The only potential benefit from participating in this study was the chance to inform practitioners, school leaders, and decision makers in BC schools about which professional learning activities NMSSTs prefer, which they believed best facilitated the acquisition of subject matter content knowledge, and which helped them become better at teaching secondary mathematics. No remuneration was provided in this study.

3.9. Potential Risks

No perceived harm, mental or physical, was anticipated from participating in this study. Minimal risk was expected. Information acquired was not sensitive data. The data collected was about the participants’ professional learning experiences in addition to some background information such as age group, gender, and years of experience. No birthdate or any other identifiable information was asked. With different forms of online distribution of the letter of invitation, no use of contact lists, and anonymous forwarding of the letter of invitation, participants in the study were anonymous. Moreover, Survey Monkey was not set to collect any information about the participants and responses were not coded, so the link between the participants and me was irrevocably broken.

3.10. Confidentiality

Data was collected only from participants who provided informed consent to participate and satisfied the NMSST participant profile in Questions 1 to 5 and 7 on the survey questionnaire. Data was collected on Survey Monkey. As part of the consent process, a disclosure statement was made indicating that data was collected on a U.S. server and that information provided may be accessed without notification under the Patriot Act. After the 2-week data collection period, the data was exported into Canada, stored, and kept confidential on a password-protected computer. Data was removed from the U.S. server during the dissertation process. Participants were anonymous and not identifiable. IP addresses and email addresses were not collected during the data
collection process. Participants were not to be contacted later, so no contact information was collected. Participants were invited to participate online via email, social media, and a Listserv. Data collected did not come from one organization and does not represent any particular institution or organization. Participants represented only themselves. To ensure further confidentiality, data was reported out in the aggregate.

3.11. Retention and Destruction of Data

Pursuant to SFU requirements, data will be retained for 2 years after the completion and publication of this dissertation. Then it will be destroyed.

3.12. Dissemination of Results

Aggregated results are reported and summarized in the dissertation, which will be made available in the SFU Library. The completed dissertation will also be available at my website at www.christineyounghusband.com/research as a link. Results from this study may be shared with school districts, independent schools, and provincial education organizations such as the BC Ministry of Education, BC Principals and Vice-Principals Association, and BC Teachers’ Federation to inform practitioners, school leaders, and decision-makers on what professional learning activities these NMSSTs preferred to strengthen their mathematics content knowledge. Papers may be submitted for publication to academic journals, such as Vector (British Columbia Association of Mathematics Teachers) and Teacher (National Council of Teachers of Mathematics), or for presentation at research conferences such as the American Education Research Association and Canadian Society for Study of Education.

3.13. Summary

Which professional learning activities do NMSSTs participate in to strengthen their mathematics content knowledge to help them teach secondary mathematics? Data
was collected from self-identifying NMSSTs using an online survey questionnaire on Survey Monkey. The survey questionnaire underwent two phases of pilot testing to establish validity of the survey instrument and consistency of the data with members of the BCAMT Executive Committee and NMSSTs from my PLN. Several revisions were made to the online survey questionnaire and approval from the SFU Office of Research Ethics was obtained. The letter of invitation, notifications to participate, and survey questionnaire were distributed and conducted online using a voluntary referral process. Members of my PLN were contacted via email, Twitter and Facebook; other potential participants were invited to participate via the BCAMT Listserv or were forwarded an invitation to participate from a colleague.

Participants in this study were over 19 years of age and did not represent one particular group or association. Based on the results of the pilot test, a data analysis plan was constructed. Results from the data analysis are found in Chapter 4: Data Analysis. Minimal risk was anticipated; participation was anonymous; and data was reported out in the aggregate. No remuneration was provided to participants. Participants volunteered their time and information about their professional learning experience in strengthening their mathematics content knowledge. The data collection period lasted 2 weeks. Due to a limited budget, time, and manpower, participants were recruited online (Baltar & Brunet, 2012) and the survey instrument was implemented online. Seventy-three proceeded with the online survey questionnaire and 62 completed the survey. Data collected is kept confidential and will be destroyed 2 years after the publication of the dissertation. The data and findings describe only those NMSSTs who participated in this study.
Chapter 4. Data Analysis

The professional learning activities that non-mathematics subject specialist teachers (NMSSTs) participated in to gain subject matter content knowledge in mathematics are summarized in the data analysis. This descriptive study focused on the professional learning experiences of NMSSTs who currently teach or have taught secondary mathematics in British Columbia (BC) schools. This section of the study describes the NMSSTs participating in this study, which professional learning activities they participated in, which they believed were most valuable, and the relationships between NMSST characteristics. Over a 2-week data collection period, 103 people opened the online survey questionnaire, 73 gave informed consent and satisfied the participant profile to proceed with the survey, and 62 completed the survey in full. Of the 73, eight did not complete Sections 2 to 5, which indicated the professional learning activities they participated in, and three did not complete most of Section 6, the background information questions (see Appendix F). Data collected from incomplete surveys were not included in the data analysis.

Of those who opened the survey questionnaire, gave informed consent, and responded with a “yes” to Question 5 (did you complete a degree in mathematics or one with significant mathematics content before teaching) were led to Question 8 (what mathematics-intensive degree did you complete) before exiting the survey. Responses to Question 8 were business administration, computer science, physics, engineering, chemistry, and biochemistry. Data analysis was not performed on Questions 1 to 5 and 7 (informed consent and participant profile). Question 6, which asks participants if they believed professional learning to be important for NMSSTs, was included in the data analysis as one of the NMSST characteristics. Univariate and bivariate analysis were conducted in this study to describe participating NMSSTs, to determine frequency and learning activities deemed most valuable to indicate which learning activity participants believed best facilitated the acquisition of the subject matter and helped them to teach
mathematics better, to identify factors that influenced these teachers to self-identify as secondary mathematics subject specialists, and to find any significant correlations between select variables.

4.1. Univariate Analysis

The univariate analysis used the data to describe the participants, to identify which professional learning activities were the most participated-in and deemed to be valuable, and to determine which learning activities were deemed best at facilitating the acquisition of the subject matter (SQ1) and were deemed to help these teachers to teach secondary mathematics better (SQ2). It concluded with a summary of “Other” responses. Data was summarized using circle graphs, histograms, central tendency, and frequency tables. Weighted sum and percent of those choosing the highest option on the Likert scale were also used to differentiate and depict what professional learning activities participants in this study found most valuable and believed best helped them.

4.1.1. The participant profile.

To take part in the study, participants were currently teaching or had taught secondary mathematics in BC schools, had not completed a degree in mathematics or mathematics-related field prior to teaching in BC schools, and participated in some professional learning to gain subject matter content knowledge in mathematics. This section captures those who satisfied the NMSST Participant Profile, the first few questions of the survey questionnaire (see Appendix F), and completed the survey questionnaire in full. To learn more about these participants, responses to questions at the end of the survey titled “Background Information” (see Appendix F) and Question 6 (the importance of professional learning for NMSSTs) underwent a univariate analysis to summarize this information. Background information included age group, gender, years of experience teaching secondary mathematics, type of BC school in which the participant taught mathematics, teaching assignment, self-identification as a subject specialist, perceived level of teaching expertise as a secondary mathematics teacher, and perceived level of subject matter content knowledge in mathematics. Background
information questions and Question 6 (importance of professional learning) were closed-ended, thus nominal and ordinal data were collected.

**Age group.** As seen in Figure 4.1, age group categories were sub-divided into 5-year intervals. There was no dominant age group. One participant did not respond. One participant was 65 years old or older. No participants were between the ages of 20 and 24. The median age group was 40 to 44 years old with an interquartile range (IQR) of 2. The mode was also 40 to 44 years old. Even though the median and mode were the same, participants generally belonged to a wide variety of age groups.

![Age group of NMSSTs (N = 62).](image)

**Figure 4.1.** Age group of NMSSTs (N = 62).

**Years of experience.** Years of experience teaching secondary mathematics in BC schools were sub-divided into 5-year intervals (Figure 4.2). The mode was 0 to 4 years of experience. The median was 10 to 14 years (IQR = 2). The median and mode are not the same. The largest group of NMSSTs participating in this study had 0 to 4 years of experience. Two-thirds of the participants had 0 to 14 years of experience (n = 40). They were in the first half of their teaching career. Three-quarters of the participants
Participants had a wide range of experience teaching secondary mathematics, most with at least 5 years of experience.

Figure 4.2. Years of experience teaching secondary mathematics (N = 62).

**BC schools.** Ninety percent (90%) of the participants currently teach or have taught secondary mathematics in BC public schools (Table 4.1). Teaching mathematics out-of-field is not practiced exclusively in public schools. Some participants have taught secondary mathematics out-of-field at independent, First Nations, and private schools. One respondent had taught secondary mathematics at a BC offshore school.
Table 4.1. BC Schools Where NMSSTs Taught Secondary Mathematics

<table>
<thead>
<tr>
<th>Type of BC school (N = 62)</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public</td>
<td>56</td>
</tr>
<tr>
<td>Independent</td>
<td>10</td>
</tr>
<tr>
<td>First Nations</td>
<td>3</td>
</tr>
<tr>
<td>Private</td>
<td>7</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
</tr>
</tbody>
</table>

**Gender.** There were more female participants \( (n = 37) \) than male \( (n = 25) \). The gender ratio in this study was 3:2, female to male.

**Self-identification.** Half of the participants \( (n = 31) \) self-identified as secondary mathematics subject specialist teachers. Self-identification was investigated further in the bivariate analysis to determine which factors influenced participants to self-identify.

**Teaching assignment.** The teaching assignment was determined by asking participants about how much of their teaching assignment was given to teaching secondary mathematics. Participants selected one of four categories on a 4-point Likert scale ranging from “most” to “very little” (Figure 4.3). Thirty-five percent (35%) of the participants taught secondary mathematics “most” of the time whereas 34% said “some” of the time. The median was “some” \( (Mdn = 2, IQR = 2) \) and the mode was “most.” The NMSST teaching assignment might depend on the teacher’s years of experience, which also revealed differing values in the median and mode (see Figure 4.2). A bivariate analysis was conducted to confirm this relationship (see Section 4.2.1).
Teaching expertise. Participants were asked to self-assess their perceived level of expertise as secondary mathematics teachers (Figure 4.4). They chose one of five descriptors on a 5-point Likert scale based on Berliner’s (2004) stages of teaching expertise: novice, advanced beginner, competent performer, proficient performer, and expert. Fifty-three percent (53%) of the participants perceived their level of teaching expertise as proficient. The median ($Mdn = 4$, $IQR = 1$) and mode indicated “proficient.” Ninety percent (90%) of the participants perceived their expertise as competent or better (Figure 4.4).
Subject matter content knowledge. Using the same 5-point Likert scale as that used for teaching expertise, participants were also asked to self-assess their perceived level of subject matter content knowledge in mathematics (Figure 4.5). Similar results were found. Fifty percent (50%) of the participants perceived their level of subject matter content knowledge in mathematics as proficient. The median ($Mdn = 4$, $IQR = 1$) and mode for subject matter content knowledge indicated “proficient.” Ninety-one percent (91%) perceived their level of subject matter content knowledge as competent or better (Figure 4.5).
**Importance of professional learning.** Question 6 asked if the participant believed that professional learning for NMSSTs to gain subject matter content knowledge in mathematics was important. They were given a 4-point Likert scale ranging from “very important” to “not important” (Figure 4.6). The median was “important” \((Mdn = 3, IQR = 1)\) while the mode was both “important” and “very important.” As seen in Figure 4.6, 78% of the participants believed that professional learning for NMSSTs was “important” or “very important.”
Summary Characteristics. In general, participants in this study:

- belong to a wide variety of age groups
- are predominantly female (a 3:2 ratio)
- possess five or more years’ experience teaching secondary mathematics
- teach in BC public schools
- teach secondary mathematics more than half of their teaching time
- half self-identified as mathematics-subject-specialist teachers
- perceive their level of teaching expertise as secondary mathematics teachers to be competent or better
- perceive their level of subject matter content knowledge in mathematics to be competent or better
- believe that professional learning for NMSSTs to strengthen their mathematics content knowledge is “important” or “very important”
4.1.2. Professional learning activities

Based on the literature review, I identified 16 professional learning activities for participants to consider (listed below). These learning activities were sub-divided into the four types of professional learning: (a) autodidactic learning activities, (b) learning communities as professional learning, (c) traditional professional development, and (d) formal learning activities. The analysis determined the most frequently used type of professional learning as well as the most frequently participated-in learning activities and learning activities believed to be most valuable in gaining subject matter content knowledge.

Individual learning activities were categorized into the following types:

• Autodidactic learning activities:
  o Mathematics Textbooks
  o Books About Mathematics
  o Teaching Secondary Mathematics
  o Online Resources

• Learning communities as professional learning:
  o School- or district-supported learning communities (Learning Communities)
  o Mentor or Colleague
  o Mathematics study or reading groups (Study or Reading Group)
  o Social Media or Listservs

• Traditional professional development:
  o Provincial or National Conferences
  o School or district professional development days (Professional Development Days)
  o Administration-initiated in-service workshops (In-service Workshops)
  o Continuing studies, non-credit workshop at university or college (Continuing Studies)
Formal learning activities:

- Completing a master or doctorate degree in mathematics or graduate degree with significant mathematics content (Master or Doctorate Degree)
- Completing an undergraduate degree in mathematics or undergraduate degree with significant mathematics content (Undergraduate Degree)
- Completing a diploma or certificate with significant mathematics content (Diploma or Certificate)
- Completing university- or college-level mathematics courses that did not lead to a degree, diploma, or certificate (Mathematics Course(s))

**Frequency and type of participation.** Respondents answered “yes” or “no” to participating in each of the 16 professional learning activities. A tally of those who responded “yes” and the sum of those results for each type of professional learning was determined and displayed in Figure 4.7. Non-responses and skipped questions were considered “no” responses. Participants could answer “yes” or “no” to more than one professional learning activity. Participants generally participated in more than one professional learning activity to gain subject matter content knowledge in mathematics. Based on the results in Figure 4.7, the type of professional learning participated in most was autodidactic professional learning activities \((n = 210)\). Participation approximately halved in learning communities \((n = 135)\) and traditional professional development \((n = 112)\). Formal professional learning activities was participated in the least \((n = 21)\).
Figure 4.7. Frequency of participation of types of professional learning (N = 62). Does not include the frequency of “Other” responses. Some “Other” responses were repeated or type was mis-categorized, which would lead to a double count or miscount of participation. “Other” responses were summarized separately in Section 4.1.4.

In Table 4.2, the frequency of participation was tabulated for each professional learning activity. The most frequently used in professional learning activities were Teaching Secondary Mathematics (n = 60) and using Mathematics Textbooks (n = 59). Referring to Online Resources (n = 49) and working with a Mentor or Colleague (n = 48) were also frequently participated in (Table 4.2). The top three most participated-in learning activities were autodidactic. However, the learning activity of working with a Mentor or Colleague was re-categorized from an autodidactic learning activity to a learning community learning activity based on the feedback of the pilot test. Grow (1991) would have categorized working with a Mentor or Colleague as self-directed learning, thus an autodidactic learning activity. NMSSTs in this study used more than one autodidactic learning activity to gain the subject matter content knowledge. Ninety-three percent (93%) of those who worked with a Mentor or Colleague did so in informal relationships and not as part of a school or district program. The least frequently
participated in learning activities in this study were completing a Diploma or Certificate ($n = 3$) and completing an Undergraduate Degree ($n = 3$) (Table 4.2).

**Table 4.2. Frequency of Participation for Each Professional Learning Activity**

<table>
<thead>
<tr>
<th>Professional learning activity</th>
<th>Frequency ($N = 62$)</th>
<th>Type of professional learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching secondary mathematics</td>
<td>60</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Mathematics textbooks</td>
<td>59</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Online resources</td>
<td>49</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Mentor or colleague</td>
<td>48</td>
<td>Learning community</td>
</tr>
<tr>
<td>Professional development days</td>
<td>45</td>
<td>Traditional</td>
</tr>
<tr>
<td>Books about mathematics</td>
<td>42</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Learning communities</td>
<td>42</td>
<td>Learning community</td>
</tr>
<tr>
<td>Provincial or national conferences</td>
<td>40</td>
<td>Traditional</td>
</tr>
<tr>
<td>Social media or Listservs</td>
<td>34</td>
<td>Learning community</td>
</tr>
<tr>
<td>Continuing studies</td>
<td>14</td>
<td>Traditional</td>
</tr>
<tr>
<td>In-service workshops</td>
<td>13</td>
<td>Traditional</td>
</tr>
<tr>
<td>Study or reading groups</td>
<td>11</td>
<td>Learning community</td>
</tr>
<tr>
<td>Master or doctorate degree</td>
<td>9</td>
<td>Formal learning</td>
</tr>
<tr>
<td>Mathematics course(s)</td>
<td>6</td>
<td>Formal learning</td>
</tr>
<tr>
<td>Undergraduate degree</td>
<td>3</td>
<td>Formal learning</td>
</tr>
<tr>
<td>Diploma or certificate</td>
<td>3</td>
<td>Formal learning</td>
</tr>
</tbody>
</table>

Respondents who answered “yes” to using Online Resources were asked a follow-up question to provide up to five types of Online Resources they used to strengthen their mathematics content knowledge. Forty-two respondents provided 116 responses. The most frequently used website was Khan Academy (Table 4.3). Participants mainly referred to mathematics and education websites that contained mathematics content such as Wolfram Alpha, Brain Pop, mathpickle.com, and educator.com. Participants also frequently visited mathematics-association websites, such as BCAMT and NCTM, or participated in Listservs. Other Online Resources not listed in Table 4.3 were podcasts, publisher websites, distance learning, Stacks Overflow, and the BC Learning Network.
Table 4.3. Types of Online Resources Used by the NMSST Respondents

<table>
<thead>
<tr>
<th>Types of online resources used</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics or education websites</td>
<td>25</td>
</tr>
<tr>
<td>Khan Academy</td>
<td>16</td>
</tr>
<tr>
<td>BCAMT, NCTM, or math Listservs</td>
<td>15</td>
</tr>
<tr>
<td>YouTube, math videos, or teaching channel</td>
<td>12</td>
</tr>
<tr>
<td>MOOC, university courses, or math contests</td>
<td>9</td>
</tr>
<tr>
<td>Blogs or teacher’s websites</td>
<td>8</td>
</tr>
<tr>
<td>Google</td>
<td>6</td>
</tr>
<tr>
<td>Wikipedia</td>
<td>5</td>
</tr>
</tbody>
</table>

Note. n = 42. BCAMT = British Columbia Association of Mathematics Teachers; NCTM = National Council of Teachers of Mathematics; MOOC = Massive Open Online Course.

**Most valuable learning activity.** The three professional learning activities that participants in this study believed were most valuable to gain subject matter content knowledge in mathematics were the practice of Teaching Secondary Mathematics, working with a Mentor or Colleague, and using Mathematics Textbooks (Table 4.4). Weighted scores were calculated from respondents who selected a particular learning activity as one of their top three most-valuable learning activities at the end of the survey questionnaire. The weighted score is the sum of frequencies for each learning activity chosen multiplied by the value of each rank. The most-valued learning activities were worth 3 points; the second-most-valued, 2 points; the third-most-valued, 1 point. Professional learning activities not selected as one of the participants’ top three most valuable were given a value of zero. The learning activities participants believed were the least valuable to gain subject matter content knowledge were In-service Workshops, Continuing Studies, and Undergraduate Degree.
Table 4.4. Most valuable professional learning activity using weighted score

<table>
<thead>
<tr>
<th>Professional learning activity</th>
<th>Most</th>
<th>Second</th>
<th>Third</th>
<th>Score</th>
<th>Type of professional learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching secondary mathematics</td>
<td>20</td>
<td>20</td>
<td>4</td>
<td>104</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Mentor or colleague</td>
<td>17</td>
<td>16</td>
<td>9</td>
<td>92</td>
<td>Learning community</td>
</tr>
<tr>
<td>Mathematics textbooks</td>
<td>12</td>
<td>4</td>
<td>12</td>
<td>56</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Online resources</td>
<td>4</td>
<td>3</td>
<td>9</td>
<td>27</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Master or doctorate degree</td>
<td>5</td>
<td>0</td>
<td>3</td>
<td>18</td>
<td>Formal learning</td>
</tr>
<tr>
<td>Provincial or national conferences</td>
<td>0</td>
<td>4</td>
<td>7</td>
<td>15</td>
<td>Traditional</td>
</tr>
<tr>
<td>Social media or Listservs</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>13</td>
<td>Learning community</td>
</tr>
<tr>
<td>Books about mathematics</td>
<td>0</td>
<td>3</td>
<td>5</td>
<td>11</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Learning communities</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>10</td>
<td>Learning community</td>
</tr>
<tr>
<td>Mathematics course(s)</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>Formal learning</td>
</tr>
<tr>
<td>Study or reading groups</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>Learning community</td>
</tr>
<tr>
<td>Professional development days</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>Traditional</td>
</tr>
<tr>
<td>Diploma or certificate</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>Formal learning</td>
</tr>
<tr>
<td>In-service workshops</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Traditional</td>
</tr>
<tr>
<td>Continuing studies</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Traditional</td>
</tr>
<tr>
<td>Undergraduate degree</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Formal learning</td>
</tr>
</tbody>
</table>

Note. $N = 62$. The score represents the weighted score. The weighted score is the sum of the frequency multiplied by the value of each category. Most = 3 points; second = 2 points; third = 1 point.

The frequency of those who participated in the learning activity of Teaching Secondary Mathematics outweigh the number who participated in a Master or Doctorate program. The learning activity deemed to be most valuable was recalculated to determine the percentage that participated in a particular learning activity and selected that learning activity as one of the top three most valuable (Table 4.5). The percentage of respondents for each learning activity was listed in descending order in Table 4.5. Frequency is the sum of the respondents from each category in Table 4.4. The percent is derived from dividing the frequency from Table 4.5 by the frequency of participation from Table 4.2. Eighty-nine percent (89%) of those who completed a master or doctoral degree and 88% of those who worked with a mentor or colleague valued these learning activities to a “great extent” whereas 73% highly valued Teaching Secondary Mathematics (Table 4.5).
Table 4.5. Percent of Participants Ranking the Top 3 Most Valuable Learning Activities

<table>
<thead>
<tr>
<th>Professional learning activity</th>
<th>Frequency</th>
<th>%</th>
<th>Type of professional learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master or doctorate degree</td>
<td>8</td>
<td>89</td>
<td>Formal learning</td>
</tr>
<tr>
<td>Mentor or colleague</td>
<td>42</td>
<td>88</td>
<td>Learning community</td>
</tr>
<tr>
<td>Teaching secondary mathematics</td>
<td>44</td>
<td>73</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Mathematics textbooks</td>
<td>28</td>
<td>48</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Online resources</td>
<td>16</td>
<td>33</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Mathematics course(s)</td>
<td>2</td>
<td>33</td>
<td>Formal learning</td>
</tr>
<tr>
<td>Diploma or certificate</td>
<td>1</td>
<td>33</td>
<td>Formal learning</td>
</tr>
<tr>
<td>Provincial or national conferences</td>
<td>11</td>
<td>28</td>
<td>Traditional</td>
</tr>
<tr>
<td>Books about mathematics</td>
<td>8</td>
<td>19</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Social media or Listservs</td>
<td>6</td>
<td>18</td>
<td>Learning community</td>
</tr>
<tr>
<td>Study or reading groups</td>
<td>2</td>
<td>18</td>
<td>Learning community</td>
</tr>
<tr>
<td>Learning communities</td>
<td>6</td>
<td>14</td>
<td>Learning community</td>
</tr>
<tr>
<td>Professional development days</td>
<td>2</td>
<td>4</td>
<td>Traditional</td>
</tr>
<tr>
<td>In-service workshops</td>
<td>0</td>
<td>0</td>
<td>Traditional</td>
</tr>
<tr>
<td>Continuing studies</td>
<td>0</td>
<td>0</td>
<td>Traditional</td>
</tr>
<tr>
<td>Undergraduate degree</td>
<td>0</td>
<td>0</td>
<td>Formal learning</td>
</tr>
</tbody>
</table>

Note. N = 62.

Professional Development Days was the learning activity participated in fifth most frequently to gain subject matter content knowledge (see Table 4.2), but tied for twelfth for most valuable learning activity (see Table 4.4) and thirteenth overall (see Table 4.5) with only 4% of those who participated in Professional Development Days choosing this learning activity as one of their top three most valuable. Many participants attended Professional Development Days but did not find the learning activity valuable in gaining subject matter knowledge. Completing an Undergraduate Degree and participating in Continuing Studies and In-service Workshops remained tied for last (see Table 4.5). However, those who did complete an Undergraduate Degree as part of their professional learning experience completed their degree in general studies with an emphasis in mathematics, science, and mathematics education. Participants who completed a Master Degree studied their degrees in numeracy or mathematics education. One participant completed a Doctorate Degree, which was in mathematics education.
Comparing most valuable learning activities. Sub-cohorts of participants were created to determine which learning activities these participants deemed most valuable. Two sub-cohorts were created: Master or Doctorate Degree and Mentor or Colleague. The selection of these sub-cohorts was based on the results found in Table 4.5 where these two learning activities showed more participants ratio-wise who believed that completing a Master or Doctorate Degree and working with a Mentor or Colleague as one of their top three most valuable learning activities to gain subject matter was more valuable than the learning activity of Teaching Secondary Mathematics, which ranked first in Table 4.4 as the most valuable learning activity. Weighted scores for each sub-cohort were tabulated in decending order in Tables 4.6 and 4.7 to compare with the results from Tables 4.4 and 4.5.

Table 4.6. Weighted Score of Master or Doctorate Degree Sub-cohort

<table>
<thead>
<tr>
<th>Professional learning activity</th>
<th>Most</th>
<th>Second</th>
<th>Third</th>
<th>Score</th>
<th>Type of professional learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master or doctorate degree</td>
<td>5</td>
<td>0</td>
<td>3</td>
<td>18</td>
<td>Formal learning</td>
</tr>
<tr>
<td>Mathematics textbooks</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>10</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Teaching secondary mathematics</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>8</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Mentor or colleague</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>7</td>
<td>Learning community</td>
</tr>
<tr>
<td>Online resources</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Provincial or national conferences</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>Traditional</td>
</tr>
<tr>
<td>Learning communities</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>Learning community</td>
</tr>
<tr>
<td>Books about mathematics</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Professional development days</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Traditional</td>
</tr>
<tr>
<td>Undergraduate degree</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Formal learning</td>
</tr>
<tr>
<td>Study or reading groups</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Learning community</td>
</tr>
<tr>
<td>Mathematics course(s)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Formal learning</td>
</tr>
<tr>
<td>Social media or Listserv</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Learning community</td>
</tr>
<tr>
<td>In-service workshops</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Traditional</td>
</tr>
<tr>
<td>Continuing studies</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Traditional</td>
</tr>
<tr>
<td>Diploma or certificate</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Formal learning</td>
</tr>
</tbody>
</table>

Note. n = 9. The score represents the weighted score. The weighted score is the sum of the frequency multiplied by the value of each category. Most = 3 points; second = 2 points; third = 1 point.

The learning activity perceived most valuable by those who completed a Master or Doctorate Degree (n = 9) was completing a Master or Doctorate Degree (see Table
Mathematics Textbooks and Teaching Secondary Mathematics ranked second and third most valuable (see Table 4.6). Participants who completed a Master or Doctorate Degree had at least 10 years of experience teaching secondary mathematics \((n = 9)\), currently teach or had taught secondary mathematics in BC public schools \((n = 7)\), and self-identified as mathematics-subject-specialists teachers \((n = 8)\).

Table 4.7. Weighted Score of Mentor or Colleague Sub-cohort

<table>
<thead>
<tr>
<th>Professional learning activity</th>
<th>Most</th>
<th>Second</th>
<th>Third</th>
<th>Score</th>
<th>Type of professional learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mentor or colleague</td>
<td>17</td>
<td>15</td>
<td>9</td>
<td>90</td>
<td>Learning community</td>
</tr>
<tr>
<td>Teaching secondary mathematics</td>
<td>16</td>
<td>15</td>
<td>3</td>
<td>81</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Mathematics textbooks</td>
<td>7</td>
<td>4</td>
<td>9</td>
<td>38</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Online resources</td>
<td>2</td>
<td>2</td>
<td>7</td>
<td>17</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Master or doctorate degree</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>13</td>
<td>Formal Learning</td>
</tr>
<tr>
<td>Provincial or national conferences</td>
<td>0</td>
<td>2</td>
<td>7</td>
<td>11</td>
<td>Traditional</td>
</tr>
<tr>
<td>Books about mathematics</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>7</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Learning communities</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td>Learning community</td>
</tr>
<tr>
<td>Social media or Listservs</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>Learning community</td>
</tr>
<tr>
<td>Mathematics course(s)</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>Formal Learning</td>
</tr>
<tr>
<td>Study or reading groups</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>Learning community</td>
</tr>
<tr>
<td>Diploma or certificate</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>Formal Learning</td>
</tr>
<tr>
<td>Professional development days</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Traditional</td>
</tr>
<tr>
<td>Continuing studies</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Traditional</td>
</tr>
<tr>
<td>Undergraduate degree</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Formal Learning</td>
</tr>
<tr>
<td>In-service workshops</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Traditional</td>
</tr>
</tbody>
</table>

*Note. \(n = 48\). The score represents the weighted score. The weighted score is the sum of the frequency multiplied by the value of each category. Most = 3 points; second = 2 points; third = 1 point.*

Participants who worked with a Mentor or Colleague \((n = 48)\) perceived that the most valuable learning activity was working with a Mentor or Colleague followed by Teaching Secondary Mathematics \((n = 47)\) and Mathematics Textbooks \((n = 47)\) (see Table 4.7). Most who worked with a Mentor or Colleague were not part of a formal mentoring program in their schools or school districts \((n = 44)\) and less than half of them self-identified as mathematics subject specialist teachers \((n = 21)\). However, Teaching Secondary Mathematics was not identified as the most valuable learning activity for those in the Mentor or Colleague sub-cohort; working with a Mentor or Colleague was
considered the most valuable learning activity for these teachers (see Table 4.7). Similar results were found for those who completed a Master or Doctorate Degree sub-cohort and this sub-cohort of teachers found completing a Master or Doctorate Degree most valuable to strengthen their subject matter content knowledge (see Table 4.6).

4.1.3. Acquisition of subject matter and improved teaching.

Respondents who answered “yes” to participating in a particular learning activity in the survey questionnaire were asked two follow-up questions that address the sub-questions of the study. The first follow-up question asked how well the learning activity strengthened their mathematics content knowledge (SQ1). The second follow-up question asked how well the learning activity helped them to teach mathematics better (SQ2). Responses given were based on a 4-point Likert scale ranging from “a great extent” to “not at all.” Zero points were given to non-responses and skipped questions. The median, mode, and percent of participants who selected “a great extent” on the Likert Scale were listed for each sub-question in Tables 4.8 and 4.9 in descending order.

The median and mode values for all learning activities listed in Tables 4.8 and 4.9 were either a “3” (“some extent”) or “4” (“a great extent”). Therefore, participating in professional learning activities was deemed helpful to strengthen the respondents’ mathematics content knowledge (SQ1). It was also deemed helpful in making these teachers teach mathematics better (SQ2). Taking the percentage of participants who selected “a great extent” in the Likert scale helped to differentiate between learning activities. In both Tables 4.8 and 4.9, the formal learning activity of completing a Master or Doctorate Degree ranked first, with 100% of the respondents believing that it helped them to “a great extent” in strengthening their mathematics content knowledge (SQ1), and 78% of the respondents believed that it helped them to “a great extent” to teach secondary mathematics better.

Formal learning activities of completing a Diploma or Certificate and completing an Undergraduate Degree ranked second and third in Table 4.8 and third and fourth in Table 4.9 with median and mode values of “4” (i.e., helped to a great extent). Although formal learning activities were participated in the least of all professional learning activities (see Figure 4.1 and Table 4.2) and were not highly valued (see Table 4.4),
respondents believed that these learning activities best helped them to strengthen their mathematics content knowledge (SQ1) and to become better at teaching secondary mathematics (SQ2).

Table 4.8. Facilitating the Acquisition of Subject Matter Content Knowledge (SQ1)

<table>
<thead>
<tr>
<th>Professional learning activity</th>
<th>Mdn</th>
<th>Mode</th>
<th>%</th>
<th>Type of professional learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master or doctorate degree</td>
<td>4</td>
<td>4</td>
<td>100</td>
<td>Formal learning</td>
</tr>
<tr>
<td>Diploma or certificate</td>
<td>4</td>
<td>4</td>
<td>67</td>
<td>Formal learning</td>
</tr>
<tr>
<td>Undergraduate degree</td>
<td>4</td>
<td>4</td>
<td>67</td>
<td>Formal learning</td>
</tr>
<tr>
<td>Teaching secondary mathematics</td>
<td>4</td>
<td>4</td>
<td>63</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Mentor or colleague</td>
<td>3.5</td>
<td>4</td>
<td>50</td>
<td>Learning community</td>
</tr>
<tr>
<td>Study or reading groups</td>
<td>3</td>
<td>3, 4</td>
<td>45</td>
<td>Learning community</td>
</tr>
<tr>
<td>Continuing studies</td>
<td>3</td>
<td>3</td>
<td>29</td>
<td>Traditional</td>
</tr>
<tr>
<td>Online resources</td>
<td>3</td>
<td>3</td>
<td>24</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Mathematics textbooks</td>
<td>3</td>
<td>3</td>
<td>22</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Learning communities</td>
<td>3</td>
<td>3</td>
<td>19</td>
<td>Learning community</td>
</tr>
<tr>
<td>Mathematics course(s)</td>
<td>3</td>
<td>3</td>
<td>17</td>
<td>Formal learning</td>
</tr>
<tr>
<td>Professional development days</td>
<td>3</td>
<td>3</td>
<td>16</td>
<td>Traditional</td>
</tr>
<tr>
<td>Provincial or national conferences</td>
<td>3</td>
<td>3</td>
<td>13</td>
<td>Traditional</td>
</tr>
<tr>
<td>Books about mathematics</td>
<td>3</td>
<td>3</td>
<td>12</td>
<td>Autodidactic</td>
</tr>
<tr>
<td>Social media or Listservs</td>
<td>3</td>
<td>3</td>
<td>9</td>
<td>Learning community</td>
</tr>
<tr>
<td>In-service workshops</td>
<td>3</td>
<td>3</td>
<td>8</td>
<td>Traditional</td>
</tr>
</tbody>
</table>

Note. The percent represents the percentage of respondents who indicated that the learning activity helped strengthen their mathematics content knowledge to “a great extent,” the highest level on the Likert Scale. SQ1 = Sub-question 1.

The autodidactic learning activity of Teaching Secondary Mathematics ranked high in Table 4.8 and 4.9, fourth and second respectively, with median and mode values of “4” (i.e., helped to a great extent). Teaching Secondary Mathematics as a learning activity consistently ranked high in the univariate analysis. It was the most frequently participated-in learning activity (see Table 4.2), perceived as the most valuable learning activity to strengthen their knowledge of mathematics (see Table 4.4), helped to “a great extent” in strengthening their mathematics-content knowledge (SQ1), and was perceived to be helpful to “a great extent” in teaching mathematics better (SQ2).
Using Social Media or Listservs and attending In-service Workshops ranked the lowest in facilitating the acquisition of subject matter content knowledge (SQ1) as seen in Table 4.8. Similarly, using Mathematics Textbooks and referring to Books About Mathematics were deemed the lowest in helping these teachers to become better secondary mathematics teachers (SQ2) as seen in Table 4.9. Working with a Mentor or Colleague and participating in a Study or Reading Group were deemed helpful by these teachers in gaining subject matter content knowledge (SQ1) and in teaching mathematics better (SQ2), ranking relatively high in Tables 4.8 and 4.9. Attending Provincial or National Conferences and Professional Development Days ranked relatively low in Tables 4.8 and 4.9.

**Learning from teaching.** Most participants in this study ($n = 60, 97\%$) engaged in Teaching Secondary Mathematics as a learning activity to strengthen their mathematics content knowledge. Teaching Secondary Mathematics was the learning activity that helped them to teach secondary mathematics better to “a great extent,” the highest level on the Likert Scale. SQ2 = Sub-question 2.
activity participated in most frequently (see Table 4.2) and was perceived to be most valuable in gaining subject matter content knowledge (see Table 4.4). Based on a 4-point Likert scale ranging from “a great extent” to “not at all,” 61% indicated that Teaching Secondary Mathematics helped them to strengthen their mathematics content knowledge (SQ1) “to a great extent” \((Mdn = 4, IQR = 1)\) and 67% said that it helped “a great extent” \((Mdn = 4, IQR = 1)\) to become better at teaching mathematics (SQ2) (Tables 4.8 and 4.9). Generally, NMSST participants in this study engaged in more than one learning activity to gain subject matter content knowledge in mathematics. As seen in Figure 4.8, NMSST participants engaged in other professional learning activities in addition to Teaching Secondary Mathematics.

![Figure 4.8](image)

**Figure 4.8.** Professional learning activities used with Teaching Secondary Mathematics in percentages \((n = 60)\).

To complement the learning activity of Teaching Secondary Mathematics to gain subject matter knowledge, teachers in this study primarily used Mathematics Textbooks \((n = 58, 97\%)\), referred to Online Resources \((n = 47, 78\%)\), and worked with a Mentor or Colleague \((n = 47, 78\%)\). NMSSTs in this study tended to participate in more than one autodidactic learning activity to strengthen their mathematics content knowledge. As
mentioned earlier, working with a Mentor or Colleague would be considered
autodidactic, but was re-categorized in this study as a learning community based on the
pilot-test feedback. Teachers whose professional learning is autodidactic require
learning activities that are flexible and accessible.

**Master degree completion.** The learning activity of completing a Master or
Doctorate Degree in mathematics or mathematics-related field ranked first in helping
teachers in this study to strengthen their mathematics content knowledge (SQ1) (see
Table 4.8) and to teach mathematics better (SQ2) (see Table 4.9). Completing a Master
or Doctorate Degree helped these teachers to “a great extent” \((Mdn = 4, IQR = 0)\).

Completing a Master or Doctorate Degree also ranked first for percentage of
participants identifying this learning activity as one of the top three most valuable
learning activities to gain subject matter content knowledge (see Table 4.5).

Eight of nine participants who completed a Master or Doctorate Degree self-
identified as mathematics-subject-specialist teachers, nine completed a master degree,
and one also completed a doctorate degree. These teachers studied in the areas of
secondary mathematics, science, numeracy, and mathematics education. Five ranked
completing a Masters or Doctorate Degree as the most valuable professional learning
activity and three ranked it the third most valuable. These participants also valued
Mathematics Textbooks, Teaching Secondary Mathematics, and Mentor or Colleague.

Six of nine were male, seven taught in public schools, and seven taught more
than half of their teaching assignments in secondary mathematics. These teachers have
15 to 19 years of experience \((Mdn = 4, IQR = 1)\) teaching secondary mathematics. Four
perceived their level of teaching expertise as expert and five as proficient performers.
Their perceived level of subject matter content knowledge varied with two self-assessing
as experts, four as proficient performers, and three as competent performers.

The median and mode values of the perceived level of teaching expertise and
perceived level of subject matter content knowledge in mathematics of participants who
completed a Master or Doctorate Degree in mathematics or a mathematics-related field
and those who did not were the same (Table 4.10). Most participants in this study had at
least 5 years of experience (see Figure 4.2) teaching secondary mathematics. Factors
that influenced these teachers in their self-identification as mathematics subject specialists are explored further in Section 4.2.2. NMSSTs participating in this study with a graduate degree in mathematics or mathematics-related field and those without such a degree perceived their level of teaching expertise and level of subject matter content knowledge to be the same, as proficient performers (Table 4.10).

**Table 4.10. Comparing NMSSTs with and without a Master or Doctorate Degree**

<table>
<thead>
<tr>
<th>Perceived level of</th>
<th>Mode</th>
<th>Mdn</th>
<th>IQR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without a master or doctorate degree (n = 53)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subject matter content knowledge</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Expertise as a mathematics teacher</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>With a master or doctorate degree (n = 9)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subject matter content knowledge</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Expertise as a mathematics teacher</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

*Note. IQR = Interquartile Range. Mode and median of 5-point Likert scale based on Berliner’s (2004) five stages of teaching expertise: 5 = expert, 4 = proficient performer, 3 = competent performer, 2 = advanced beginner, and 1 = novice.*

### 4.1.4. Other professional learning activities.

Participants were given an opportunity to provide “Other” responses regarding their professional learning experiences after each section or type of professional learning in the survey questionnaire: autodidactic learning activities, learning communities as professional learning, traditional professional development, and formal learning activities. The specific learning activities provided by respondents in the “Other” short answer questions after each section of the survey questionnaire (see Appendix F) that were different from the learning activities already considered in the study are listed below.

**Autodidactic learning activities.** Twenty-five participants responded with 62 short-answer responses for “Other” autodidactic learning activities. Seventeen mentioned learning community examples (e.g., talking to other teachers), 15 mentioned traditional professional development examples (e.g., conferences), four mentioned formal learning examples (e.g., university math courses), and three were autodidactic
(e.g., online resources, reading books about math). Eight comments referred to pedagogy development (e.g., special education, special needs, and student anxiety). “Other” autodidactic learning activities that were different from those already mentioned in the study were doing the mathematics on your own ($n = 15$) and learning from students ($n = 1$).

**Learning communities as professional learning.** Twelve participants responded with 21 “Other” learning community responses. Ten mentioned traditional professional development activities (e.g., conferences), two mentioned formal learning activities (e.g., master degree), and five mentioned autodidactic learning activities (e.g., learning as part of the job). “Other” learning community activities that were different from those mentioned in this study were informal dialogue with friends or colleagues ($n = 3$) and “lesson study” ($n = 1$). Informal dialogues with friends or colleagues could be one-off conversations that are situational and in passing. A “lesson study” is a classroom inquiry amongst a group of teachers who work and learn together to share their personal results and experiences around a particular lesson of common interest.

**Traditional professional development.** Six responded with 8 “Other” traditional professional development responses. One response was a learning community example (e.g., working with a colleague) and 2 were about general pedagogy development (e.g., growth mindset and experiential education). Three “Other” learning activities that were different from those already mentioned in this study were observing teachers ($n = 1$), leading workshops ($n = 2$), and continuing education for credits ($n = 2$).

**Formal learning activities.** No responses were given. However, at the end of this section, participants were asked to provide any “Other” professional learning activities not yet mentioned. One mentioned he or she was the mathematics department head (autodidactic), another attended Pacific Institute of Mathematical Sciences lectures (traditional), and one completed a Master of Arts in Curriculum Studies (formal).

**Final comments.** Twenty-four participants provided final comments about their professional learning experience. Six said that they had sufficient subject matter preparation in mathematics without a major or minor in mathematics. Three emphasized
the importance of finding a colleague who was a good mentor and expert in the field. Four mentioned the best way to learn the subject matter was to work with students and learn the subject matter on the job. Six highlighted the lack of accessibility to participate in more professional learning due to geography, the need for more release time, and the need for more financial support. Finally, three participants said the limiting factor to teaching secondary mathematics was not the lack subject matter content knowledge, but pedagogy.

4.2. Bivariate Analysis

The bivariate analysis looked at relationships among NMSST characteristics and sub-questions: which professional learning activities did you believe best facilitated the acquisition of the subject matter (SQ1) and which professional learning activities do you believe helped you to become a better secondary mathematics teacher (SQ2). NMSST characteristics included age group, years of experience, teaching assignment, perceived level of expertise, perceived level of subject matter content knowledge, and the importance of professional learning for NMSSTs. The first bivariate analysis attempts to confirm the relationship between years of experience and teaching assignment as highlighted in the univariate analysis in Section 4.1.1. The second analysis looked at which NMSST characteristics contributed to NMSSTs self-identifying as a mathematics subject specialist. The third analysis uncovered the relationship between helping to strengthen mathematics content knowledge (SQ1) and teaching secondary mathematics better (SQ2). The fourth analysis examined the relationships between strengthening mathematics content knowledge (SQ1), teaching secondary mathematics better (SQ2), perceived level of expertise, and perceived level of subject matter content knowledge. The final analysis found significant relationships between six NMSST characteristics.

4.2.1. Years of experience and teaching assignment.

The mode and median values differed for the NMSST characteristics of years of experience teaching secondary mathematics and the NMSST’s teaching assignment in the univariate analysis. The results in both variables were almost bimodal differing only
by one or two participants. This unique finding merited further investigation to see whether there was a significant relationship between these two NMSST characteristics.

Table 4.11 shows the observed values for years of experience in 5-year increments versus teaching assignment ranging from “most” to “very little” on a 4-point Likert Scale. Table 4.12 shows the expected values. The $\chi^2$-value was calculated to be 27.823 with 18 degrees of freedom (e.g., (number of rows - 1) x (number of columns – 1)), but the critical value at $p < .05$ was 28.859. The null-hypothesis was not rejected. The calculated $\chi^2$-value was greater than or equal to the critical value. This finding was verified on Excel with a calculated = CHI.TEST value of .068. However, the = CHI.TEST value indicates that the relationship between years of experience and teaching assignment would be significant at $p < .10$ where the critical value is 25.989. In the end, the relationship may have been found significant at $p < .05$ between the categorical data of the two NMSST characteristics had the sample size been larger.

Table 4.11. Frequency Distribution of Teaching Experience versus Assignment (Observed Values) $(N = 62)$

<table>
<thead>
<tr>
<th>Years of experience</th>
<th>Most</th>
<th>More than half</th>
<th>Some</th>
<th>Very little</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 4</td>
<td>0</td>
<td>1</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>5 to 9</td>
<td>3</td>
<td>1</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>10 to 14</td>
<td>7</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>15 to 19</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>20 to 24</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>25 to 29</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>30+ years</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 4.12. Expected Values for Teaching Expertise and Assignment (N = 62)

<table>
<thead>
<tr>
<th>Years of experience</th>
<th>Most</th>
<th>More than half</th>
<th>Some</th>
<th>Very little</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 4</td>
<td>5.410</td>
<td>1.721</td>
<td>5.164</td>
<td>2.705</td>
</tr>
<tr>
<td>5 to 9</td>
<td>4.328</td>
<td>1.377</td>
<td>4.131</td>
<td>2.164</td>
</tr>
<tr>
<td>10 to 14</td>
<td>5.049</td>
<td>1.607</td>
<td>4.820</td>
<td>2.525</td>
</tr>
<tr>
<td>15 to 19</td>
<td>3.246</td>
<td>1.033</td>
<td>3.098</td>
<td>1.623</td>
</tr>
<tr>
<td>20 to 24</td>
<td>1.443</td>
<td>0.459</td>
<td>1.377</td>
<td>0.721</td>
</tr>
<tr>
<td>25 to 29</td>
<td>1.443</td>
<td>0.459</td>
<td>1.377</td>
<td>0.721</td>
</tr>
<tr>
<td>30+ years</td>
<td>1.082</td>
<td>0.344</td>
<td>1.033</td>
<td>0.541</td>
</tr>
</tbody>
</table>

4.2.2. Self-identifying as mathematics subject specialist teachers.

Participants were asked if they self-identified as a secondary mathematics subject specialist teacher with a “yes” or “no” response (see Appendix F). Fifty percent (50%) of the respondents said “yes.” A $\chi^2$-Test was used to determine any significant relationships between the ordinal data of age group, years of experience, teaching assignment, perceived level of expertise, perceived level of subject matter content knowledge, perceived importance of professional development, and nominal data of gender with the nominal data of the “yes” or “no” response. One respondent did not answer the age group and years of experience questions in the survey questionnaire, thus $n = 61$. For the remaining characteristics listed in Table 4.13, $N = 62$. Degrees of freedom were calculated from (number of rows - 1) x (number of columns - 1). The rows were the number of options there were in the Likert scale for each NMSST characteristic. The number of columns was two, representing the number of options for self-identifying. Critical values derived from a chi-square ($\chi^2$) table at $\alpha = .05$. For a significant correlation, the $\chi^2$ value must greater than or equal to the critical value. To verify these findings, $p$-values were also calculated in Excel using = CHISQ.TEST.

As seen in Table 4.13, NMSST characteristics that influenced participants to self-identify as mathematics subject specialists were years of experience teaching secondary mathematics, teaching assignment (e.g., approximate amount of secondary mathematics being taught), and perceived level of expertise as a secondary mathematics teacher.
Table 4.13. Chi-Square Test of Self-Identification and NMSST Characteristics

<table>
<thead>
<tr>
<th>Category</th>
<th>df</th>
<th>( \chi^2 )</th>
<th>Critical value</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age group(^a)</td>
<td>9</td>
<td>2.256</td>
<td>16.919</td>
<td>-</td>
</tr>
<tr>
<td>Experience(^a)</td>
<td>6</td>
<td>23.283(^*)</td>
<td>12.592</td>
<td>.001</td>
</tr>
<tr>
<td>Assignment(^b)</td>
<td>3</td>
<td>33.039(^*)</td>
<td>7.815</td>
<td>&lt; .050</td>
</tr>
<tr>
<td>Expertise(^b)</td>
<td>4</td>
<td>20.042(^*)</td>
<td>9.488</td>
<td>&lt; .050</td>
</tr>
<tr>
<td>SMCK(^b)</td>
<td>4</td>
<td>6.294</td>
<td>9.488</td>
<td>.178</td>
</tr>
<tr>
<td>Gender(^b)</td>
<td>1</td>
<td>1.725</td>
<td>0.0429</td>
<td>.189</td>
</tr>
<tr>
<td>Importance(^b)</td>
<td>3</td>
<td>3.195</td>
<td>7.815</td>
<td>.289</td>
</tr>
</tbody>
</table>

*Note. Experience = years of experience; Assignment = teaching assignment; Expertise = perceived level of teaching expertise; SMCK = perceived level of subject matter content knowledge; Importance = believed importance of professional learning for NMSSTs. Critical values retrieved from Chi-Square Distribution Table at [http://sites.stat.psu.edu/~mga/401/tables/Chi-square-table.pdf](http://sites.stat.psu.edu/~mga/401/tables/Chi-square-table.pdf)

\(^a\)\( n = 61. \(^b\)\( n = 62. \)^p < .05.

4.2.3. Facilitating acquisition and teaching mathematics better.

Sixteen professional learning activities considered in this study were subdivided into four types of professional learning: autodidactic, learning community, traditional professional development, and formal learning. Participants responded “yes” or “no” in the survey questionnaire about participating in each learning activity. Those responding “yes” were asked two follow-up questions per learning activity: SQ1 (strengthening mathematics content knowledge) and SQ2 (becoming a better mathematics teacher). In Table 4.14, “n” is the number who answered “yes” to participating (see Table 4.2), “df” is the degrees of freedom (\( n – 2 \)), “\( r_s \)” is the Spearman’s Rank Coefficient calculated from \( r = \frac{6 \sum d^2}{n(n-1)} \), and “rho-crit” is the critical value (Zar, 1984) at \( \alpha = .05 \) (two-tailed). If the calculated Spearman’s rank coefficient was greater than or equal to the critical value, the relationship was significant.
Table 4.14. Spearman’s Ranked Correlation Coefficients between Strengthening Mathematics Content Knowledge (SQ1) and Becoming a Better Mathematics Teacher (SQ2)

<table>
<thead>
<tr>
<th>Professional learning activity</th>
<th>n</th>
<th>df</th>
<th>$r_s$</th>
<th>rho-crit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autodidactic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mathematics textbooks</td>
<td>59</td>
<td>57</td>
<td>0.609</td>
<td>0.261</td>
</tr>
<tr>
<td>Books on Mathematics</td>
<td>42</td>
<td>40</td>
<td>0.624</td>
<td>0.313</td>
</tr>
<tr>
<td>Teaching mathematics</td>
<td>60</td>
<td>58</td>
<td>0.737</td>
<td>0.259</td>
</tr>
<tr>
<td>Online resources</td>
<td>49</td>
<td>47</td>
<td>0.733</td>
<td>0.288</td>
</tr>
<tr>
<td>Learning Community</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning communities</td>
<td>41</td>
<td>39</td>
<td>0.805</td>
<td>0.317</td>
</tr>
<tr>
<td>Mentor or colleague</td>
<td>48</td>
<td>46</td>
<td>0.809</td>
<td>0.291</td>
</tr>
<tr>
<td>Study or reading groups</td>
<td>11</td>
<td>9</td>
<td>0.898</td>
<td>0.700</td>
</tr>
<tr>
<td>Social media or Listservs</td>
<td>34</td>
<td>32</td>
<td>0.824</td>
<td>0.350</td>
</tr>
<tr>
<td>Traditional Professional Development</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>National or provincial conferences</td>
<td>40</td>
<td>38</td>
<td>0.915</td>
<td>0.321</td>
</tr>
<tr>
<td>Professional development days</td>
<td>45</td>
<td>43</td>
<td>0.882</td>
<td>0.301</td>
</tr>
<tr>
<td>In-service workshops</td>
<td>13</td>
<td>11</td>
<td>0.996</td>
<td>0.618</td>
</tr>
<tr>
<td>Continuing education</td>
<td>14</td>
<td>12</td>
<td>0.855</td>
<td>0.587</td>
</tr>
<tr>
<td>Formal Learning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Master or doctorate degree</td>
<td>9</td>
<td>7</td>
<td>0.738</td>
<td>0.786</td>
</tr>
<tr>
<td>Undergraduate degree</td>
<td>3</td>
<td>1</td>
<td>1.000</td>
<td>-</td>
</tr>
<tr>
<td>Diploma or certificate</td>
<td>3</td>
<td>1</td>
<td>1.000</td>
<td>-</td>
</tr>
<tr>
<td>Mathematics course(s)</td>
<td>6</td>
<td>4</td>
<td>0.857</td>
<td>-</td>
</tr>
</tbody>
</table>

Note. df = degrees of freedom; $r_s$ = Spearman’s Ranked Correlation Coefficient; rho-crit = critical value; - = no critical values were available. The $r_s$ value must greater than or equal to the rho-crit to be significant.

The learning activity learning communities had $n = 41$, which was one less than what was recorded in Table 4.2 because one respondent answered SQ1 but not SQ2. All other learning activities had the same $n$-value as listed in Table 4.2. There were significant relationships found between strengthening content knowledge (SQ1) and teaching mathematics better (SQ2) for the first 12 learning activities listed in Table 4.14. These learning activities were autodidactic, learning communities, and traditional professional development. The learning activity of completing a Master or Doctorate Degree did not reject the null hypothesis by .003 at $p < .05$. However, the relationship between strengthening mathematics content knowledge and becoming a better mathematics teacher for those who completed a Master or Doctorate Degree would be
significant at $p < .10$, where the critical value is .714. The relationship may have been found significant at $p < .05$ for the learning activity of completing Master or Doctorate Degree had the sample size been larger. Significance for the remaining three formal learning activities of completing an Undergraduate Degree, completing a Diploma or Certificate, and completing a Mathematics Course could not be determined due to small sample sizes. However, the Spearman Rank Correlation Coefficient for the learning activities of completing an Undergraduate Degree and completing a Diploma or Certificate was 1.000. Overall, participants believed that learning the subject matter helped them to teach secondary mathematics better.

### 4.2.4. Teaching expertise and subject matter content knowledge.

The sub-question responses for strengthening content knowledge (SQ1) and helping to teach secondary mathematics better (SQ2) were compared to the participants’ perceived level of expertise (Expertise) and subject matter content knowledge (SMCK) for the first 12 learning activities listed in Table 4.14. This analysis did not include any formal learning activities because the null hypothesis was not rejected or significance could not be determined. The $n$-values, degrees of freedom, and rho-critical values used in Table 4.14 apply to Table 4.15. The Spearman’s Ranked Correlation Coefficients ($r_s$) were calculated using $r = \frac{6 \Sigma d^2}{n^3-n}$ and compared to the rho-critical values at $\alpha = .05$. The absolute values of the correlation coefficients greater than or equal to the rho-critical value are significant. Significant correlations are identified with an asterisk in Table 4.15.

Fourteen significant correlations were found (Table 4.15). The learning activities of Teaching Secondary Mathematics and use of Social Media and Listservs showed positive relationships for all four permutations (Table 4.15). Learning communities showed two positive correlations: the first correlation was between strengthening content knowledge (SQ1) and teaching mathematics better, and the second correlation was between strengthening content knowledge and perceived level of expertise (Table 4.15). The learning activity of reading Books about Mathematics revealed one positive correlation between strengthening content knowledge (SQ1) and perceived level of expertise (Table 4.15). The learning activity of Mathematics Textbooks revealed three of four positive correlations (Table 4.15) where the perceived level of expertise and helping
to teach mathematics better (SQ2) were not found significant because the perceived level of expertise was self-assessed by participants as “proficient performers” but participants ranked the learning activity of Mathematics Textbooks second to last in helping them to teach mathematics better (SQ2) (see Table 4.9).

Table 4.15. Spearman’s Ranked Correlation Coefficients of Perceived Levels of Expertise and Subject Matter Content Knowledge with Sub-questions 1 and 2

<table>
<thead>
<tr>
<th>Professional learning activity</th>
<th>Expertise SQ1</th>
<th>Expertise SQ2</th>
<th>SMCK SQ1</th>
<th>SMCK SQ2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autodidactic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mathematics textbooks</td>
<td>0.408*</td>
<td>0.240</td>
<td>0.285*</td>
<td>0.369*</td>
</tr>
<tr>
<td>Books about mathematics</td>
<td>0.391*</td>
<td>0.198</td>
<td>0.273</td>
<td>0.299</td>
</tr>
<tr>
<td>Teaching secondary mathematics</td>
<td>0.409*</td>
<td>0.389*</td>
<td>0.283*</td>
<td>0.322*</td>
</tr>
<tr>
<td>Online resources</td>
<td>0.218</td>
<td>0.040</td>
<td>0.187</td>
<td>0.225</td>
</tr>
<tr>
<td>Learning community</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning communities</td>
<td>0.371*</td>
<td>0.385*</td>
<td>0.265</td>
<td>0.053</td>
</tr>
<tr>
<td>Mentor or colleague</td>
<td>0.241</td>
<td>0.098</td>
<td>0.235</td>
<td>0.132</td>
</tr>
<tr>
<td>Study or reading groups</td>
<td>0.070</td>
<td>-0.139</td>
<td>-0.025</td>
<td>-0.218</td>
</tr>
<tr>
<td>Social media or Listservs</td>
<td>0.359*</td>
<td>0.397*</td>
<td>0.352*</td>
<td>0.373*</td>
</tr>
<tr>
<td>Traditional professional development</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>National or provincial conferences</td>
<td>0.268</td>
<td>0.291</td>
<td>0.167</td>
<td>0.141</td>
</tr>
<tr>
<td>Professional development days</td>
<td>0.068</td>
<td>0.026</td>
<td>-0.021</td>
<td>-0.039</td>
</tr>
<tr>
<td>In-service workshops</td>
<td>0.287</td>
<td>0.275</td>
<td>0.168</td>
<td>0.157</td>
</tr>
<tr>
<td>Continuing education</td>
<td>0.284</td>
<td>0.307</td>
<td>0.474</td>
<td>0.378</td>
</tr>
</tbody>
</table>

Note. Expertise = perceived level of teaching expertise; SMCK = perceived level of subject matter content knowledge; SQ1 = Sub-question 1 (strengthened mathematics content knowledge); SQ2 = Sub-question 2 (teach mathematics better). 
Rho-critical values are the same as those found in Table 4.14 at α = .05
*p < .05.

The learning activity of Teaching Secondary Mathematics revealed significant relationships between all four NMSST characteristics of perceived level of expertise, perceived level of subject matter content knowledge, strengthening content knowledge (SQ1), and helping to teach mathematics better (SQ2) (see Table 4.15). This finding shows that learning by doing and experiential learning for NMSSTs to gain subject matter content knowledge is important. NMSSTs in this study ranked the learning activity of Teaching Secondary Mathematics first in the most frequently used learning activity
(see Table 4.2), believed it was the most valuable learning activity to gain subject matter content knowledge (see Table 4.4), and ranked this learning activity relatively high in both strengthening content knowledge (SQ1) (see Table 4.8) and teaching mathematics better (SQ2) (see Table 4.9). Using Social Media and Listservs have the same positive correlations as Teaching Secondary Mathematics as seen in Table 4.15, but do not rank high in participation, value, strengthening content knowledge, and helping to teach mathematics better.

The significant relationships found in Table 4.15 show that in the learning activity of Teaching Secondary Mathematics, for example, the perceived level of subject matter content knowledge positively correlated to a belief that the learning activity facilitated the acquisition of the subject matter content knowledge (e.g., SMCK and SQ1). This pattern is repeated with perceived level of expertise and strengthening content knowledge (SQ1), perceived level of subject matter content knowledge and helping to teach mathematics better (SQ2), and perceived level of expertise and helping to teach mathematics better (SQ2). The learning activity of Teaching Secondary Mathematics was deemed to help NMSSTs to strengthen their mathematics knowledge and develop expertise. In this study, NMSSTs said that learning communities helped them to develop their expertise. Mathematics Textbooks helped them to strengthen their subject matter content knowledge.

4.2.5. Relationships between NMSST characteristics.

The final bivariate analysis compared NMSST characteristics with each other to determine any significant relationships. NMSST characteristics considered were the importance of participating in professional learning to NMSSTs (Importance), age group (Age), years of experience (Experience), teaching assignment (Assignment), perceived level of teaching expertise (Expertise), and perceived level of subject matter content knowledge (SMCK). Gender and self-identification as a mathematics subject specialist were excluded from this analysis because they were “yes” or “no” nominal data. The type of BC school a teacher taught at was also excluded from this analysis because it resulted in nominal data where each respondent could have more than one response.
The Spearman Rank Correlation Coefficients ($r_s$) were calculated from the data collected from the Background Information questions at the end of the online survey questionnaire (see Appendix F) that included a Likert Scale of more than two categories (i.e., age group). The coefficients calculated are listed in Table 4.16. The $n$-value was 61. One respondent was excluded from this analysis because he or she did not answer all the questions in the Background Information section. Therefore, the degree of freedom was 59 and the critical value was 0.257 at $\alpha = 0.05$ (two-tailed). Correlation coefficients that were greater than or equal to the critical value were found significant at $p < .05$ and indicated below in Table 4.16 with an asterisk.

### Table 4.16. Spearman’s Ranked Correlation Coefficients of NMSST Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Importance</th>
<th>Age</th>
<th>Experience</th>
<th>Assignment</th>
<th>Expertise</th>
<th>SMCK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Importance</td>
<td>-</td>
<td>0.140</td>
<td>0.162</td>
<td>0.335*</td>
<td>0.155</td>
<td>0.142</td>
</tr>
<tr>
<td>Age</td>
<td>0.140</td>
<td>-</td>
<td>0.522*</td>
<td>0.167</td>
<td>0.143</td>
<td>0.115</td>
</tr>
<tr>
<td>Experience</td>
<td>0.162</td>
<td>0.522*</td>
<td>-</td>
<td>0.585*</td>
<td>0.624*</td>
<td>0.518*</td>
</tr>
<tr>
<td>Assignment</td>
<td>0.335*</td>
<td>0.167</td>
<td>0.585*</td>
<td>-</td>
<td>0.644*</td>
<td>0.539*</td>
</tr>
<tr>
<td>Expertise</td>
<td>0.155</td>
<td>0.143</td>
<td>0.624*</td>
<td>0.644*</td>
<td>-</td>
<td>0.669*</td>
</tr>
<tr>
<td>SMCK</td>
<td>0.142</td>
<td>0.115</td>
<td>0.518*</td>
<td>0.539*</td>
<td>0.669*</td>
<td>-</td>
</tr>
</tbody>
</table>

*Note. Importance = believed importance of professional learning for NMSSTs; Age = age group; Experience = years of experience teaching mathematics; Assignment = teaching assignment; Expertise = perceived level of teaching expertise; SMCK = perceived level of subject matter content knowledge.

Rho-critical value = .257 at $\alpha = .05$ (two-tailed).  
*p < .05.

$n = 61.$

Eight significant NMSST characteristic relationships were found:

- Importance of professional development and teaching assignment
- Years of experience and age group
- Years of experience and teaching assignment
- Years of experience and teaching expertise
- Years of experience and subject matter content knowledge
- Teaching assignment and teaching expertise
- Teaching assignment and subject matter content knowledge
- Teaching expertise and subject matter content knowledge

The NMSST characteristic of participants believing that participating in learning activities for NMSSTs to strengthen their content knowledge is important was correlated to the NMSST characteristic of teaching assignment. In this case, the more secondary mathematics NMSSTs were assigned to teach, the more important the participants believed that participating in learning activities for NMSSTs was. Another correlation was found between age group and years of experience. The older the participant was, the more likely s/he had more teaching experience (Table 4.16).

The remaining six relationships listed above found from Table 4.16 were positive correlations between four NMSST characteristics: years of experience, teaching assignment, perceived level of expertise, and perceived level of subject matter content knowledge. These characteristics are related with each other, or inter-related, as shown in Figure 4.9, where connections between all four characteristics were found. Thus, these are key characteristics in the professional growth of NMSSTs as practicing secondary mathematics teachers in BC schools. However, self-identification for NMSSTs was influenced by only three of four of these characteristics (see Table 4.13). The NMSST characteristic of perceived level of subject matter content knowledge did not influence NMSSTs in this study to self-identify as mathematics subject specialists.

![Figure 4.9. Inter-related NMSST characteristics.](image-url)
4.3. Summary

What professional learning activities have NMSSTs who currently teach or have taught secondary mathematics in BC schools participated in to gain subject matter content knowledge in mathematics? The most frequently participated-in learning activity (see Table 4.2) and the one perceived to be most valuable (see Table 4.4) was the act of Teaching Secondary Mathematics. The second most participated in learning activity was using Mathematics Textbooks (see Table 4.2). The perceived second most valuable learning activity to gain subject matter content knowledge was working with a Mentor or Colleague (see Tables 4.4 and 4.5). However, the professional learning activity of completing a Master or Doctorate Degree had the highest percentage of its participants ranking this learning activity as one of their top three most valuable learning activities (see Table 4.5) and believing it best facilitated the acquisition of subject matter content knowledge (SQ1) (see Table 4.8) and best helped these teachers improve their teaching of secondary mathematics (see Table 4.9). Moreover, the sub-cohorts of participants who completed a Master or Doctorate Degree (see Table 4.6) and those who worked with a Mentor or Colleague (see Table 4.7) believed that these learning activities, respectively, most valuable to gain subject matter content knowledge.

The profile of NMSSTs participating in the study was determined. The participants came from a wide variety of age groups, were predominantly female, had five or more years of experience teaching secondary mathematics, were currently teaching or had taught secondary mathematics in public schools, and may or may not have self-identified as mathematics subject specialists. Their perceived level of teaching expertise and level of subject matter knowledge were self-assessed as competent or better (see Section 4.1.1). Those who used Teaching Secondary Mathematics to gain the subject matter also participated in Mathematics Textbooks, Online Resources, and working with a Mentor or Colleague (see Figure 4.8). The most common online resources were mathematics or education websites, particularly Khan Academy.

Teachers in this study participated in more than one professional learning activity to gain subject matter content knowledge in mathematics. The type of professional learning participated in most often was autodidactic (see Figure 4.1). Participants believed that all 16 learning activities strengthened their mathematics content knowledge.
(SQ1) and helped them to teach secondary mathematics better (SQ2) to “some extent” or “a great extent” (see Tables 4.8 and 4.9). The median and mode of perceived level of teaching expertise and perceived level of subject matter knowledge were self-assessed as “proficient.” Participants who completed a Master or Doctorate Degree and those who did not had the same self-assessment and believed their levels of expertise and subject matter knowledge were proficient (see Table 4.10).

Other findings included the following: graduate degrees were completed in numeracy and mathematics education; mentoring relationships were informal; degrees completed with significant mathematics were in engineering, physics, education, chemistry, biochemistry, computer science, and business administration. (Those with degrees involving significant mathematics content did not take the rest of the survey.) Other professional learning activities that respondents participated in to strengthen their mathematics content knowledge were doing mathematics, learning from students, engaging in informal dialogues, participating in a lesson study, leading workshops, observing teachers, and becoming a mathematics department head. Other comments provided at the end of the survey stated the importance of having a good mentor, noted the lack of accessibility to professional learning opportunities, said that the participant had sufficient subject matter content knowledge without a mathematics background, and opined that the limiting factor for NMSSTs was not subject matter content knowledge but pedagogy.

The relationship between the NMSST characteristics of years of experience teaching secondary mathematics and the number of secondary courses taught within the NMSST’s teaching assignment revealed no significant relationship using the Chi-Square Test, even though each characteristic differed in values in median and mode. The null hypothesis was almost rejected but not at 95% confidence. The relationships may have been found significant using the Chi-Square Test if the sample size had been larger in this study. However, years of experience and teaching assignment were significantly correlated using Spearman’s Rank Correlation Coefficient in the final bivariate analysis comparing six NMSST characteristics as two of four inter-related characteristics.

NMSST characteristics that influenced participants in this study in the self-identification as mathematics subject specialists were perceived level of expertise, years
of experience, and teaching assignment (i.e., how many mathematics courses they were teaching) (see Table 4.13). This outcome slightly differs from Table 4.16 where an inter-relationship was found between the NMSST characteristics of perceived level of expertise, years of experience, teaching assignment, and perceived level of subject matter content knowledge. The NMSST characteristic of perceived level of subject matter content knowledge in mathematics was not a significant factor that influenced NMSSTs in this study to self-identify as mathematics subject specialists.

Other positive correlations found were between years of experience and age group and between teaching assignment and the perceived importance of professional learning for NMSSTs (see Table 4.16). Significant relationships were also found between which professional learning activities participants believed best facilitated the acquisition of content knowledge (SQ1) and helped them to become better secondary mathematics teachers (SQ2) for 12 activities that were categorized as autodidactic, learning communities, and traditional professional development (see Table 4.14). Completing a Master or Doctorate Degree did not reject the null hypothesis in this analysis at \( p < .05 \) and the remaining formal learning activities could not determine significance due to small sample sizes. Generally, NMSSTs participating in learning activities to gain subject matter believed that it helped them strengthen their subject matter knowledge and helped them to teach secondary mathematics better.

Finally, there were 14 positive correlations found out of a possible 64 combinations between perceived level of expertise, perceived level of subject matter content knowledge, strengthening mathematics content knowledge (SQ1), and helping to teach mathematics better (SQ2) for five of 16 learning activities (see Table 4.15). Teaching Secondary Mathematics and using Social Media or Listservs showed all four relationships as significant. Learning Communities had two significant relationships with perceived level of expertise and Books about Mathematics had one (see Table 4.15). Mathematics Textbooks had three of four significant relationships, where no significance was found between perceived level of expertise and teaching mathematics better (SQ2) (see Table 4.15). In the end, the learning activity of Teaching Secondary Mathematics was deemed to support NMSSTs in gaining subject matter content knowledge and building expertise, whereas the learning activity of Learning
Communities was deemed to support building expertise, and the learning activity of Mathematics Textbooks correlated with gaining subject matter content knowledge.
Chapter 5. Discussion

The professional learning activities non-mathematics subject specialist teachers (NMSSTs) who teach or have taught secondary mathematics in British Columbia (BC) schools participated in to gain subject matter in mathematics are identified in this section of the study. The purpose of this chapter is to highlight some of the findings from Chapter 4, discuss their relationship to the literature, and answer the research question and sub-questions. The univariate analysis identified the professional learning activities NMSSTs have participated in and which learning activities they used most often, found most valuable, and believed to be most helpful. The bivariate analysis identified significant relationships between NMSST characteristics and factors that influence NMSSTs to self-identify as mathematics subject specialists. Based on the findings and the discussion, recommendations to practitioners, school leadership, and future research are made in Chapter 6 as possible considerations to implement to support NMSSTs with their subject matter content knowledge development in mathematics.

5.1. Relationship to the Literature

Many of the findings in this study support the literature in the literature review. However, some of the findings did not fully align with what the literature suggests because parts of what was found in the data analysis were unexpected. Details of these findings are discussed further in Section 5.1.2. Findings that supported the literature and ones that differed from what was expected are highlighted below in sub-sections titled common themes and unexpected findings.
5.1.1. Common themes.

Four themes emerge from the findings that were aligned to the literature. First, subject matter content knowledge was acquired by studying the teaching materials. Second, learning the subject matter was enhanced by the guidance and support from an expert in the field. Third, developing expertise takes time, requires experience, and involves deliberate practice. Finally, the learning activity of Professional Development Days was regularly attended but not regarded to be relatively helpful or valuable in gaining subject matter content knowledge. The following sub-sections explore these themes further.

Learning from experience.

I feel teaching Math really helped me to understand Math.

(Participant 53)

The learning activity of Teaching Secondary Mathematics was identified as the most frequently participated-in professional learning activity and was also perceived as the most valuable learning activity to gain subject matter content knowledge (see Tables 4.4 and 4.5). Teaching Secondary Mathematics also ranked fourth overall in facilitating the acquisition of the subject matter (SQ1) and second in helping these teachers to become better secondary mathematics teachers (SQ2) (see Tables 4.8 and 4.9). NMSSTs in this study learned the subject matter as out-of-field teachers from the act of teaching. They learned the subject matter on the job via experiential learning: starting with a concrete experience in the classroom, reflecting on practice, making adoptions to understanding, and trying again (Kolb, 1984; Osterman & Kottkamp, 1993; Schön, 1983, 1987). Teachers were learning the subject matter as it was related to teaching (Garet et al., 2001; Hill & Ball, 2004; Loucks-Horsley & Matsumoto, 1999). Learning the subject matter, like developing a profound understanding of foundational mathematics or learning specialized content knowledge, was not learned formally in a classroom environment, but on the job teaching mathematics (Ball et al., 2008; Ericsson & Poole, 2016; Ma, 2010).

Chinese teachers developed a “deep, broad, and thorough” (Ma, 2010, p. 120) understanding of the subject matter content from teaching mathematics; they taught
each grade level from K-7. Chinese teachers gained teaching experience and subject matter expertise over time after teaching several cycles of each grade level. Although NMSSTs were not strategically assigned to teach different grades levels of mathematics sequentially from year-to-year from Grades 8 to 12 so that they could learn the subject matter over time in 5-year intervals, NMSST characteristics of years of experience, teaching assignment, and perceived level of expertise were significant factors influencing respondents to self-identify as mathematics subject specialists, indicating that NMSSTs were learning the subject matter over time from experience.

Participants did not learn the subject matter from the learning activity of Teaching Secondary Mathematics alone, but complemented their professional learning experience with other learning activities such as using Mathematics Textbooks, referring to Online Resources, and working with a Mentor or Colleague (see Figure 4.8). As was discovered in the elementary schools in China, studying the teaching materials intensely was one strategy used to develop subject matter content knowledge in mathematics (Ma, 2010). Studying the teaching materials intensely involved understanding the curriculum as prescribed by government, referring to mathematics textbooks and teacher guides, and teaching each grade level of mathematics through a 7-year cycle (Ma, 2010). In this study, Teaching Secondary Mathematics, Mathematics Textbooks, and Online Resources were the most frequently participated in learning activities, followed by working with a Mentor or Colleague (see Table 4.2). Teachers were learning the subject matter on the job. They learned the subject matter to teach the subject matter. They also used textbooks, websites, and mentors to help them prepare for teaching the subject matter to students.

Although the teacher's guide or provincial curriculum were not one of the 16 learning activities considered in this study, respondents indicated that participating in the learning activities of Mathematics Textbooks and Online Resources were used most frequently to complement the learning activity of Teaching Secondary Mathematics to strengthen their mathematics content knowledge (see Table 4.8). The textbook was the most used study material to gain subject matter content knowledge much as it was in China (Ma, 2010) (see Table 4.2 and Figure 4.8). The learning activity of using Mathematics Textbooks was the second most frequently used learning activity (see Table 4.2), perceived as third- and fourth-most-valuable (see Tables 4.4 and 4.5), but
was deemed ninth in facilitating the acquisition of subject matter (see Table 4.8) and fifteenth in helping teachers to teach mathematics better (see Table 4.9). Mathematics textbooks were deemed to help participants in this study to “some extent” in gaining subject matter content knowledge (see Table 4.8) and developing their level of subject matter content knowledge (see Table 4.15). Participants did not regard Mathematics textbooks as helpful to improve their teaching of mathematics and developing their perceived level of expertise (see Tables 4.9 and 4.15).

Mathematics Textbooks used by participants were likely the same learning resources used by students. Moreover, Mathematics Textbooks are cost effective, accessible, and convenient to use. For these reasons NMSSTs used Mathematics Textbooks as a learning activity, even though participants believed that Mathematics Textbooks did not help them to learn the subject matter easily or to teach mathematics better in comparison to other professional learning activities. On the other hand, NMSSTs in this study also frequently participated in (see Table 4.2) the learning activity of working with a Mentor or Colleague, which was perceived to be valuable (see Tables 4.4 and 4.5) and helpful in gaining the subject matter (SQ1) and in teaching mathematics better (SQ2) to a “great extent” (see Table 4.8 and 4.9). Although the mentoring was predominantly informal for teachers in this study and not structured into research groups as they were in Ma’s study (2010), NMSSTs were able to self-direct their learning to acquire the expertise of a Mentor or Colleague for extra help.

The learning activity of referring to Online Resources provides the same level of flexibility, accessibility, and convenience as Mathematics Textbooks to gain subject matter content knowledge in mathematics. Online Resources were used frequently as a learning activity (see Table 4.2 and Figure 4.8) but were perceived to be moderately valuable (see Tables 4.4 and 4.5) and “somewhat” helpful in acquiring the subject matter and teaching mathematics better (see Tables 4.8 and 4.9). Many participants in this study frequented the Khan Academy website and other education websites to learn the subject matter (see Table 4.1). Teachers can easily and conveniently access information online while on the job or preparing to teach at home to deepen their understanding of the subject matter. Moreover, accessing help from a Mentor or Colleague contributed to the learning experiences of NMSSTs in this study.
Effective professional development needs to be ongoing, onsite, and connected with other teaching professionals to actively engage in the subject matter, to learn over time, and to apply what was learned (Garet et al., 2001; Loucks-Horsley & Matsumoto, 1999). Furthermore, according to Grow’s (1991) definition of self-directed learning, the learning activity of working with a Mentor or Colleague would have been considered an autodidactic learning activity in this study. However, it was relabelled in this study as a learning community based on the feedback of the pilot test. Thus, NMSSTs in this study used more than one autodidactic learning activity to gain the subject matter content knowledge. Participants were self-directed in their learning; they learned for and by themselves (Grow, 1991). The rigor of teaching mathematics required NMSSTs in this study to learn and understand the subject matter at some level of competence (Ball et al., 2008; Ma, 2010; Turnuklu & Yesildere, 2007).

*Learning from an expert.*

Mentorship is by far the most valuable resource we can access.  
( Participant 49)

In Western Australia, policymakers identified out-field teaching in mathematics and teacher shortages as a problem and created an initiative to attract more students to study mathematics and science at university by lowering tuition to these programs (McConney & Price, 2009). The logic was that having more students graduating from mathematics and science programs would mean more students enrolling to become mathematics and science teachers. This would take 4 years to realize. In the meantime, another initiative was created to improve the subject matter content knowledge of junior mathematics teachers so that these teachers could teach senior mathematics (McConney & Price, 2009). Several strategies were employed where junior mathematics teachers were learning from experts in the field (McConney & Price, 2009). Junior mathematics teachers engaged in intensive coursework after school, in in-class projects, and in mentoring from senior mathematics teachers (McConney & Price, 2009). NMSSTs in this study highly valued the professional learning activities of completing a Master or Doctorate Degree and working with a Mentor or Colleague to strengthen their mathematics content knowledge.
Overall, the professional learning activity of Teaching Secondary Mathematics was identified as the most valuable learning activity to gain subject matter knowledge. However, sub-cohorts of NMSSTs who completed a Master or Doctorate Degree and worked with a Mentor or Colleague stood out as different. The sub-cohort of participants who completed a Master or Doctorate Degree indicated that completing their graduate degree was the most valuable learning activity (see Table 4.6). It was considered the most valuable learning activity ratio-wise to learn the subject matter (see Table 4.5). The sub-cohort of participants who worked with a Mentor or Colleague also believed working with a Mentor or Colleague was the most valuable learning activity to strengthen their knowledge of mathematics (see Table 4.7) and the second most valuable learning activity (see Tables 4.4 and 4.5). Moreover, the learning activity of completing a Master or Doctorate Degree was believed to best facilitate the acquisition of knowledge (see Table 4.8). Participants believed this learning activity helped them to become better secondary mathematics teachers (see Table 4.9). This was also true for other formal learning activities such as completing a Diploma or Certificate and completing an Undergraduate Degree (see Tables 4.8 and 4.9), which are professional learning activities that would be facilitated by an expert in the field.

In formal learning situations and working with a Mentor or Colleague, there is an expert in the field imparting knowledge and expertise to the learner, in this case, the NMSST. “Training with immediate feedback... can be an incredibly powerful way to improve performance” (Ericsson & Poole, 2016, p. 128). In the context of deliberate practice, an expert in the field provides feedback, support, and guidance to NMSSTs to deepen or enhance their understanding. Creating partnerships with higher education or with those who have subject matter expertise is another opportunity to help mathematics teachers to deeply understand mathematical ideas and communicate these ideas effectively (Ontario Ministry of Education, 2016; Papick, 2011). For example, the recently implemented K-12 mathematics strategy in Ontario incorporates professional learning of teachers and school leaders with subject matter experts in the classroom and schools to support their professional learning (Ontario Ministry of Education, 2016).

Nine participants in this study enrolled in higher education programs such as completing a Master or Doctorate Degree or Diploma or Certificate (see Table 4.2). Participating in formal learning activities provided by universities requires additional time,
money, and possibly transportation to access these learning opportunities for practicing teachers. Not all teachers can commit at least 2 years to graduate studies, afford tuition, or access a university due to geography or program availability. This is unlike autodidactic learning activities such as Teaching Secondary Mathematics, Mathematics Textbooks, and Online Resources, which tend to be accessible, affordable, and more convenient to use for practicing teachers, as shown with higher participation rates in Table 4.2. However, NMSSTs with teaching assignments made up of mostly secondary mathematics courses had more teaching experience and believed professional learning for NMSSTs was important (see Table 4.16). Completing a Master or Doctorate degree was believed to best facilitate the acquisition of knowledge (see Table 4.8) and to help these teachers to become better secondary mathematics teachers (see Table 4.9).

The junior mathematics teachers participating in the Western Australia initiative appreciated the guidance and support from an experienced senior mathematics teacher who mentored and encouraged them as they tried out new ideas and took control of their learning (McConney & Price, 2009). As in this study, teachers who worked with experts in the field reported deepening their understanding of the subject matter (McConney & Price, 2009) and believed that they taught mathematics better (McConney & Price, 2009). Assigned mentors or instructional coaches can support teachers to transfer knowledge from formal learning activities, such as a summer intensive course, into the classroom (Papick, 2011). It is essential for NMSSTs to have knowledgeable instructors focused on subject matter development and content that is related to teaching (Garet et al., 2001; Hill & Ball, 2004; Ma, 2010). For these reasons, working with an expert in the field, the professional learning activities of completing a Master or Doctorate Degree, and working with a Mentor or Colleague were perceived to be valuable learning activities to gain subject matter content knowledge in mathematics.

Building expertise.

We, as teachers, always hear “it’s just Grade 8 or it’s junior age… anyone can teach it.” I highly disagree. (Participant 16)

Teachers build expertise over time from experience (Berlin, 2001, 2004). However, expertise is not developed from experience alone (Ericsson & Poole, 2016; Hattie, 2012). From the data, significant correlations were found between facilitating the
Subject matter content knowledge contributes to the development of pedagogical content knowledge. Understanding of the subject matter influenced how teachers taught the subject matter (Ball, 1988; Ball et al., 2005; Even, 1993; Ma, 2010). When NMSSTs have a deeper understanding of the subject matter in mathematics, teaching secondary mathematics might evolve from being algorithmic in nature to being conceptual (Ball et al., 2005; Even, 1993; Hattie, 2012; Lachner & Nückles, 2016; Ma, 2010). The NMSST characteristic of perceived level of expertise as a secondary mathematics teacher was positively correlated to the participants’ perception of how well the learning activity they participated in facilitated the acquisition of subject matter (SQ1) and participating in the learning activity helped them to teach secondary mathematics better (SQ2) for 3 of 16 learning activities considered in this study (see Table 4.15). The learning activities to which the perceived level of expertise positively correlated strengthening knowledge (SQ1) and teaching mathematics better (SQ2) were Teaching Secondary Mathematics, Learning Communities, and Social Media or Listservs (see Table 4.15). From this finding, learning on the job and connecting with others in the field face-to-face or online helped NMSSTs to develop their perceived level of expertise.

A profound understanding of mathematics or specialized content knowledge in mathematics is acquired from teaching mathematics (Ma, 2010; Ball et al., 2008). Teaching Secondary Mathematics, as mentioned earlier, was the most frequently used professional learning activity and was perceived to be most valuable in gaining subject
matter content knowledge in mathematics. NMSSTs in this study were experiential learners (Kolb, 1984). The learning activities where both perceived level of expertise and level of subject matter content knowledge were positively correlated to strengthening knowledge (SQ1) and teaching mathematics better (SQ2) were Teaching Secondary Mathematics and Social Media or Listerves (see Table 4.15). Participants gained knowledge from learning on the job, learning by doing, and engaging in practical experiments in their teaching practice (National Research Council, 2000; Papick, 2011; Schön, 1983, 1987), and they gained experience and developed expertise over time (Berliner, 2001).

**Professional development.**

I wish I could have been granted release time to learn from a colleague with a math degree or that there would be more Pro-D, specifically for teachers with no math background. (Participant 54)

Professional Development Days were frequently attended by participants in this study as suggested by Loucks-Horsley & Matsumoto (1999). Seventy-three percent (73%) of the participants participated in Professional Development Days to gain subject matter content knowledge in mathematics, ranking this learning activity fifth out of 16 for frequency of use (see Table 4.2). Public schools, for example, have 6 days / year in the school calendar dedicated to Professional Development Days, which are non-instructional days designed to provide teachers with an opportunity to engage in professional learning outside of the classroom. Professional Development Days are short-term, one-time sessions that are not necessarily subject matter content specific and tend not to promote or facilitate ongoing, collaborative professional learning as a follow-up to ensure that what was learned transfers into the classroom (Ericsson & Pool, 2016; Garet et al., 2001; Loucks-Horsley & Matsumoto, 1999; Papick, 2011). Professional Development Days are not designed for ongoing, onsite collaborative learning, which could support NMSSTs with their subject matter content acquisition.

From the perspective of deliberate practice, the problem is obvious: attending lectures, mini-courses, and the like offers little or no feedback and little or no chance to try something new, make mistakes, correct the mistakes, and gradually develop a new skill.

(Ericsson & Pool, 2016, p. 135)
Effective professional learning entails ongoing time to work with colleagues collectively and collaboratively (Garet et al., 2001; Hill & Ball, 2004; Loucks-Horsley & Matsumoto, 1999; National Research Council, 2000). Use of Professional Development Days was not perceived to be a valuable learning activity to gain subject matter knowledge, ranking twelfth out of 16 (see Table 4.4). Only 4% of those who participated in this learning activity rated it as one of their top three most valuable learning activities (see Table 4.5). Although participants indicated that Professional Development Days did facilitate the acquisition of subject matter and helped these teachers teach mathematics better to “some extent” (see Table 4.8 and 4.9), only 16% of those who participated in the learning activity believed that it helped them to “a great extent” (see Tables 4.8 and 4.9).

The learning activity of Professional Development Days was regularly attended and highly sought after by teachers to support their professional learning, particularly with the implementation of “B.C.’s New Curriculum” (Province of British Columbia, 2016). However, the data suggests that it was not perceived as a valuable learning activity to gain the subject matter content knowledge and did not help to a “great extent” in facilitating the subject matter and helping these teachers to teach mathematics better. This finding is consistent with the literature, where Professional Development Days that are frequently attended one-time events set away from the working environment of the teacher, are deemed as less effective. Effective professional learning entails ongoing, collaborative learning opportunities where teachers can experiment, reflect, gather feedback, and try again in the context of their working environment (Garet et al., 2001; Hill & Ball, 2004; Loucks-Horsley & Matsumoto, 1999). Professional Development Days are usually lecture style and not normally subject matter specific. Schools, districts, and teachers traditionally invest a significant amount of time and money into Professional Development Days. A redesign should be considered if the ultimate goal is to change teaching practice.

5.1.2. Unexpected findings.

Some findings in this study were expected based on the literature and other pieces of data collected and analyzed during the study. The first unexpected finding was self-identification as mathematics subject specialist teachers. The second was the
participant’s self-assessment of their perceived level of expertise as a secondary mathematics teacher and perceived level of subject matter content knowledge in mathematics. The third unexpected finding was the possibility of learning in isolation. The following sub-sections further describe the unexpected findings.

**Self-identification.** When university students study to become secondary mathematics teachers, they are required to complete a major or minor in mathematics (BC Ministry of Education, 2016a). This would include a specific number of mathematics courses at the 300- and 400-level in addition to completing the prerequisite 100- and 200-level courses before entering teacher-education programs in BC specializing in secondary mathematics (PDP, n.d. [at SFU]; TEO, n.d. [at UBC]; UFV, n.d.; UNBC, n.d.; UVic, n.d.). These teachers would likely enter the workforce as secondary mathematics subject specialists. NMSSTs would have gone through a similar process in terms of subject matter preparation in a teachable subject area they originally wanted to major or minor in prior to entering teacher education.

When initially assigned to teach mathematics, secondary NMSSTs would have likely self-identified as subject specialist teachers in the subject area they had majored or minored in. Participants in this study were asked in a “yes” or “no” question about whether they self-identified as secondary mathematics subject specialist teachers. Fifty percent (50%) of the participants responded “yes.” Self-identification was investigated further in the bivariate analysis to determine which NMSST characteristics influenced participants to self-identify. Seven NMSST characteristics were considered: age group, years of experience, teaching assignment, perceived level of expertise, perceived level of subject matter knowledge, gender, and importance of professional learning for NMSSTs. Three characteristics were found significant: years of experience, teaching assignment, and perceived level of expertise (see Table 4.13).

The misalignment comes from a second bivariate analysis, which looked for significant correlations among NMSST characteristics. The analysis involved ordinal data; therefore NMSST characteristics of gender and self-identification were excluded. There was a positive correlation found between years of experience of teaching secondary mathematics and age group (see Table 4.16). This correlation would be a natural relationship; one gains experiences, as one grows older. A second correlation
was found between the participants’ teaching assignments (e.g., the number of secondary mathematics classes taught per year) and the importance of professional learning to strengthen their mathematics-content knowledge for NMSSTs (see Table 4.16). This would also be a natural relationship as one would be more interested in learning more mathematics as one was assigned more secondary mathematics classes to teach.

Six additional relationships were found between four NMSST characteristics (see Figure 4.9). Positive correlations were found between years of experience, teaching assignment, perceived level of expertise, and perceived level of subject matter content knowledge. As seen in Figure 4.9, these NMSST characteristics are inter-related. These four characteristics were similar to the characteristics that were found significant in the self-identification of NMSSTs as mathematics subject specialists except for the NMSST characteristic of perceived level of subject matter content knowledge in mathematics. Interestingly, this characteristic was not found to be significant to participants in this study regarding self-identification as mathematics subject specialists. It was, however, significant to those who entered the teaching profession with the intent of becoming secondary mathematics teachers. Pre-service mathematics teachers defined their subject specialty based on their subject matter preparation in mathematics.

NMSST characteristics that influenced NMSST participants in the self-identification as subject specialists were all experience oriented. Years of experience would indicate the time spent teaching secondary mathematics in BC schools. Teaching assignment is the amount of secondary mathematics taught per school year. Perceived level of expertise is derived from the time spent teaching secondary mathematics. The more mathematics courses a teacher teaches over time, the more teaching experience was gained. The more experience a teacher acquires, the more the teacher perceives his or her level of expertise to be enhanced. However, for NMSSTs in this study, the perceived level of subject matter content knowledge in mathematics was not a significant factor for these teachers to self-identify as mathematics subject specialists.

**Self-assessment.** Subject matter content knowledge as defined by Shulman (1986) considers the organization of knowledge in the mind of the teacher that goes beyond facts and concepts of the domain that is separate from the pedagogy specific to
the subject matter. The literature suggests two levels of subject matter content knowledge. One example by Ball et al. (2008) sub-divided subject matter knowledge into two domains: common content knowledge and specialized content knowledge. Common content knowledge is the material taught to and learned by students and specialized content knowledge is the subject knowledge and skill unique to teaching (Ball et al., 2008). Although Ball et al. (2008) identified two domains for subject matter content knowledge, there is no clear line that distinguishes or separates the two (Hurrell, 2013).

Hattie (2012), on the other hand, identified two levels of content knowledge by comparing experienced and expert teachers. Experienced teachers had a surface-level understanding of the subject matter. Expert teachers have a deeper level of understanding. What distinguished experienced from expert teachers was how the subject is organized in the mind (Hattie, 2012). Whereas Lachner and Nückles (2016) differentiate between the conceptual process-oriented instruction of mathematicians who are rich in content knowledge and the get-the-answer algorithmic product-oriented instruction of mathematics teachers who are experienced in mathematics pedagogy. The approach and effects of delivery in teaching the subject matter to Grade 11 students differed between the two instructional styles due to the mathematicians’ and teachers’ level of understanding of the subject matter (Lachner & Nückles, 2016).

When the survey instrument was created, this study used Shulman’s (1986) definition of subject matter content knowledge, which is not sub-divided into two distinct categories as described in other literature (Ball et al., 2008; Hattie, 2012; Lachner & Nückles, 2016). Participants self-assessed in the Background Information of the survey questionnaire (see Appendix F) their perceived levels of subject matter knowledge and expertise on one continuum using a 5-point Likert scale based on Berliner’s (2004) five stages of teaching expertise. Ninety-one percent (91%) of the participants perceived their level of subject matter knowledge in mathematics to be competent or better. Fifty percent (50%) believed they were proficient (see Table 4.5). Similarly, 90% of the participants self-assessed their perceived level of expertise as secondary mathematics teachers as competent or better, and 53% believed they were proficient (see Table 4.4). Seventy-four percent (74%) of the participants had at least 5 years of experience teaching secondary mathematics in BC schools and 26% had 0 to 4 years of experience.
In Ireland, almost half of the teachers sampled in the Riordain and Hannigan (2011) indicated that they did not have the teaching qualification to teach mathematics, but more than three-quarters of them claimed that their qualifications were sufficient. In the Riordain and Hannigan study, there were a significant percentage of out-of-field teachers who felt that their qualifications were sufficient. This was also indicated in the “Other” responses found at the end of study that stated, “I don’t think my content knowledge has ever been a limiting factor” (Participant 50), “Content is not a problem” (Participant 9), and “I already had a very solid mathematical background from taking IB math and calculus in Grade 12” (Participant 24). These comments are similar to the Riordain and Hannigan findings of believing that subject matter content preparation from university was not integral to their qualifications to teach mathematics. When certified in BC with a professional teaching certificate, there are no restrictions on subject area or grade level a teacher can teach (BC Ministry of Education, 2017a). In essence, they are qualified to teach in BC in spite of subject matter preparation.

In this study, participants were not asked if they believed they were qualified to teach mathematics. They were asked if they would self-identify as subject matter specialists (see this chapter’s “Self-identification” section). They were also asked for their perceived level of subject matter content knowledge and level of teaching expertise. The perceived level of subject matter content knowledge and level of teaching expertise was investigated further by looking at two sub-groups: one group had completed a Master or Doctorate Degree in mathematics or mathematics-related field (n = 9) and the other group had not (n = 53). Those who completed a Master or Doctorate Degree as professional learning had at least 10 years of experience teaching secondary mathematics. Completing a Master or Doctorate Degree was considered the most helpful learning activity to facilitate the acquisition of subject matter (SQ1) and was deemed to have helped these teachers to teach mathematics better (SQ2) (see Tables 4.8 and 4.9). When comparing the median and mode for perceived levels of subject matter content knowledge and teaching expertise, participants who completed a Master or Doctorate Degree did not differ from the other respondents (Table 4.10).

Both sub-groups perceived their level of subject matter content knowledge in mathematics and level of expertise as secondary mathematics teachers as proficient. There are two interpretations of this finding. One interpretation is that the subject matter
content knowledge acquired from the learning activities, in general, is comparable to the subject matter content knowledge acquired by participants who completed a Master or Doctorate Degree in mathematics education or numeracy. A second interpretation is that the participants who did not complete a Master or Doctorate Degree as part of their professional learning experience believed that they are proficient in the common content knowledge of mathematics, as defined by Ball et al. (2008). The participants without a graduate degree believed that they understand and can do the mathematics; the same mathematics students should be able to learn and understand, competently.

On the other hand, those who did complete a graduate degree in mathematics education or numeracy gained a deeper understanding of the subject matter with formal learning in the context of teaching. Not only did these teachers complete a degree in mathematics education, thus formally changing their credentials and subject specialty by retraining to become secondary mathematics subject specialist teachers, but they also likely gained more knowledge about mathematics and teaching mathematics to understand that there is more specialized content knowledge, as defined by Ball et al. (2008), to learn. As a result, those who did not complete a Master or Doctorate Degree may have overestimated their levels of subject matter content knowledge and teaching expertise, whereas those who did complete an advanced degree may have underestimated.

**Learning in isolation.** The top three professional learning activities participants in this study most frequently participated in to gain subject matter content knowledge in mathematics were Teaching Secondary Mathematics, Mathematics Textbooks, and Online Resources (see Table 4.2). These professional learning activities are autodidactic, or self-taught. Note that self-taught does not mean learning in isolation (Solomon, 2003). NMSSTs in this study were self-directed in their learning and wished to learn the subject matter with autodidactic learning activities. Self-directed learners can ask for help or assistance from a mentor or coach, when needed, to gather the expertise they require in their professional learning experience (Grow, 1991). This was confirmed in Table 4.2 where the professional learning activities of working with a Mentor or Colleague and attending Professional Development Days were the fourth and fifth most frequently participated-in learning activities to gain subject matter knowledge.
The literature suggests effective professional development is ongoing, active, collaborative, connected to practice, and led by those who are knowledgeable in the field (Garet et al., 2001; Hill & Ball, 2004). Unlike Professional Development Days, which are 1-day or 1-shot events situated away from the classroom or teaching environment, autodidactic professional learning activities have one of the core attributes of more effective professional learning activities—namely being on-site in the workplace. NMSSTs are learning on the job, experientially, gaining subject matter content knowledge from teaching, doing questions, and going online. These out-of-field teachers are discovering on the job what students need to learn, and three-quarters of these teachers reached out for help from a Mentor or Colleague, which Grow (1991) defines as part of Stage 4: Self-directed Learning. Most of the mentoring relationships were informal and were not part of a school- or school-district mentorship program intended to help teachers with their professional learning.

Teaching generally occurs in isolation from other teachers. NMSSTs are gaining subject matter content knowledge from Teaching Secondary Mathematics, from Mathematics Textbooks, and from Online Resources. All three autodidactic learning activities can be achieved without the support of an expert, mentor, or colleague. “In schools, the prevailing ‘egg-carton’ structure, in which teachers work chiefly as isolates with little interaction with colleagues, undermines opportunities for teachers to test or be exposed to alternative understandings” (Lortie as cited in Spillane et al., 2006, pp. 56-57). Teachers as learners are physically isolated from their peers while they teach and are likely alone at home preparing to teach. NMSSTs are learning in isolation. They do not receive formative feedback from an expert when they teach or learn from a textbook or computer to gain a deeper understanding of the subject matter. Receiving immediate feedback from an expert in the field is an integral part of deliberate practice (Ericsson & Pool, 2016). The only feedback they may receive on a regular ongoing basis is from their students, but students are not experts in the field.

As a result, these teachers may not accurately or appropriately self-diagnose any deficiencies in their level of subject matter understanding. Learning in isolation is difficult (Spillane et al., 2006). NMSSTs should gain subject matter knowledge with a knowledgeable instructor in a collaborative learning environment working with peers and engage in content that is related to practice (Garet et al., 2001; Hill & Ball, 2004). A
“sense-making practice is stretched over teachers, specialists, and school administrators and is not purely a solo enterprise” (Spillane et al., 2006, p. 61). Teaching Secondary Mathematics supplemented by using Mathematics Textbooks, and Online Resources as the most frequently used professional learning activities suggest that NMSSTs in this study could be learning in isolation from other teachers and experts in the field, preventing these teachers as learners from asking questions, exchanging ideas, or sense-making. Two participants in this study learned the subject matter only from Teaching Secondary Mathematics and using Mathematics Textbooks or Online Resources. They were learning in isolation from others. Furthermore, working with a Mentor or Colleague may or may not be an ongoing learning experience for NMSSTs. It might be periodic, not face-to-face, or a one-time learning opportunity, whereas NMSSTs who completed a Master or Doctorate Degree learned the subject matter in a learning environment where experts in the field and other practicing mathematics teachers work together in a professional learning community over a period of time.

In Ma’s (2010) study, teachers collaborated with colleagues in research groups as ongoing professional learning to develop subject matter content knowledge. Some NMSSTs in this study may have worked with a Mentor or Colleague and many had participated in many learning activities aside from Teaching Secondary Mathematics, using Mathematics Textbooks, and referring to Online Resources. Participating in learning communities helped NMSSTs in this study develop their perceived level of expertise from learning the subject matter (SQ1) and teaching mathematics better (SQ2) (see Table 4.15). Participants in learning communities ranked sixth overall for most frequently participated-in learning activity (see Table 4.2), and ninth for the most valuable learning activity (see Table 4.4). Learning communities were deemed tenth in facilitating the acquisition of subject matter (SQ1) (see Table 4.8) and seventh in helping to teach mathematics better (SQ2) (see Table 4.9). There was a positive correlation between strengthening knowledge (SQ1) and teaching mathematics better (SQ2) (see Table 4.14). Collaborating with colleagues, learning from an expert in the field, and practicing with immediate feedback contributes to ongoing professional learning.
5.2. Answering the Research Question

Which professional learning activities have non-mathematics subject specialist teachers (NMSSTs) who teach or have taught secondary mathematics in British Columbia (BC) schools participated in to gain subject matter content knowledge in mathematics? NMSSTs in this study participated in more than one professional learning activity to gain subject matter content knowledge in mathematics (see Table 4.2). Participating in professional learning activities helped these teachers to strengthen their mathematics content knowledge (see Table 4.8) and helped them to become better secondary mathematics teachers (see Table 4.9). There was a correlation between facilitating the acquisition of subject matter (SQ1) and in learning that subject matter helped these teachers to teach secondary mathematics better (SQ2) for most learning activities (see Table 4.14). The professional learning activities NMSSTs in this study participated in were Teaching Secondary Mathematics, Mathematics Textbooks, Online Resources, Master or Doctorate Degree, and Mentor or Colleague.

Participants in this study participated mostly in autodidactic learning activities (see Figure 4.7). Autodidactic learning activities are affordable, accessible, and convenient. Teachers can learn the subject matter when and where they need it. Moreover, autodidactic learning activities are not constrained by time or the formalities of formal learning. Autodidactic learning activities are convenient for NMSSTs in this study to learn the subject matter on the job as practicing secondary mathematics teachers. Conversely, the least frequently participated-in type of professional learning was formal learning activities. Unlike autodidactic learning activities, formal learning activities are not easily accessible, affordable, or flexible because they require tuition, fixed learning times and locations, and achievement of prescribed learning outcomes.

The most frequently participated-in professional learning activity was the act of Teaching Secondary Mathematics (see Table 4.2). The second, third, and fourth most frequently participated-in learning activities (see Table 4.2) were also the same learning activities that Teaching Secondary Mathematics participants used to supplement their professional learning (see Figure 4.8). These learning activities were using Mathematics Textbooks, referring to Online Resources, and working with a Mentor or Colleague. For NMSSTs in this study, the freedom and flexibility of autodidactic learning activities were
of most frequent use due to factors such as accessibility, affordability, and convenience. These teachers learned subject matter on the job with the support of a Mentor or Colleague. NMSSTs in this study were self-directed, experiential learners.

The participants perceived that the most valuable professional learning activity to gain subject matter content knowledge was the act of Teaching Secondary Mathematics (see Table 4.4). The next two most-valued professional learning activities were working with a Mentor or Colleague and using Mathematics Textbooks (see Table 4.4). However, the percentage of those choosing a particular learning activity as one of their top three most valuable learning activities revealed different results. The learning activity of completing a Master or Doctorate Degree ranked first followed by working with a Mentor or Colleague and the act of Teaching Secondary Mathematics (see Table 4.5). The learning activity deemed most valuable was investigated further with those who worked with a Mentor or Colleague (see Table 4.7) and those who completed a Master or Doctorate Degree (see Table 4.6). In both cases, the learning activity in question was found most valuable. Both working with a Mentor or Colleague and completing a Master or Doctorate Degree were perceived as valuable because both learning activities have experts in the field to assist NMSSTs with their subject matter knowledge development.

5.2.1. Answering Sub-question 1.

Which professional learning activities do these teachers believe best facilitated their acquisition of subject matter content knowledge in mathematics? The professional learning activity that best facilitated the acquisition of subject matter content knowledge in mathematics for NMSSTs in this study was completing a Master or Doctorate Degree, which was followed by two other formal learning activities: completing a Diploma or Certificate in a mathematics-related field and Undergraduate Degree with significant mathematics content (see Table 4.8). The act of Teaching Secondary Mathematics ranked fourth overall for perceived help in strengthening the mathematics content knowledge of these teachers (see Table 4.8). Participating in any one of the 16 professional learning activities considered in this study helped NMSSTs in this study to “some extent” in acquiring the subject matter content knowledge. Participants in this study believed that professional learning was “important” or “very important” for NMSSTs (see Figure 4.6). In the end, the learning activities that were deemed best in facilitating
the acquisition of subject matter content knowledge for NMSSTs in this study were formal learning activities in which NMSSTs are dependent learners (Grow, 1991) and their instructors are the experts in the field who are responsible for designing, facilitating, assessing, and evaluating the NMSSTs’ professional learning experiences over a set period.

5.2.2. Answering Sub-question 2.

Which professional learning activities in gaining subject matter content knowledge in mathematics do these teachers believe helped them to teach secondary mathematics better? The professional learning activity that participants believed helped them the best to teach secondary mathematics was completing a Master or Doctorate Degree (see Table 4.9). Unlike Sub-question 1, the learning activities that helped these teachers believed helped them to teach mathematics better aside from completing a Master or Doctorate Degree were the act of Teaching Secondary Mathematics, completing a Diploma or Certificate, and completing an Undergraduate Degree (see Table 4.9). The same three formal learning activities remain high on this list even though there was no correlation found between SQ1 (facilitating of the acquisition of the subject matter content knowledge) and SQ2 (helping NMSSTs to teach secondary mathematics better) due to small sample sizes (see Table 4.14). However, the fact that the learning activity of Teaching Secondary Mathematics ranked second and the belief that this learning activity helped them to teach secondary mathematics better reinforces the idea of experiential learning, learning by doing, and building expertise. Generally, participating in professional learning activities to gain subject matter content knowledge in mathematics was believed to help NMSSTs in this study to teach secondary mathematics better to “some extent.”

5.3. Summary

NMSSTs in this study most frequently participated in autodidactic professional learning activities to gain subject matter content knowledge in mathematics, specifically Teaching Secondary Mathematics, Mathematics Textbooks, and Online Resources.
Autodidactic learning activities are accessible, affordable, and convenient to meet the subject matter learning needs of NMSSTs on the job. NMSSTs primarily learned the subject matter experientially by teaching the subject matter and learning from textbooks and online resources, such as Khan Academy, to understand the subject matter. With this self-directed, autonomous approach to professional learning, many of the NMSSTs worked informally with a Mentor or Colleague to support their professional learning.

The act of Teaching Secondary Mathematics was perceived to be the most valuable learning activity to gain subject matter content knowledge in mathematics. The second most valuable was working with a Mentor or Colleague. This finding suggests NMSSTs valued experiential learning with the added support of a Mentor or Colleague. When looking at two sub-cohorts of participants, the cohort of those who completed a Master or Doctorate Degree and the other cohort of those who worked with a Mentor or Colleague believed the most valuable learning activity was their respective sub-cohort learning activity. Once again, the importance of learning from an expert in the field is emphasized. However, some participants may have learned the subject matter without the help of an expert in the field, learning the subject matter in isolation.

Participants primarily gained subject matter content knowledge from experience. Their level of subject matter content knowledge and level of expertise were self-assessed as proficient, regardless of whether the respondent had completed a Masters or Doctorate Degree or not. Most of the participants had 5 or more years of experience teaching secondary mathematics in BC schools, and generally, they believed that participating in professional learning helped to some extent to strengthen their mathematics content knowledge and helped them to teach mathematics better. How well these teachers believed the professional learning activity facilitated the acquisition of the subject matter content knowledge was correlated to the belief that the learning activity helped them to teach mathematics better. Although this correlation could not be confirmed for formal learning activities, participants believed completing a Masters or Doctorate Degree, Undergraduate Degree, and Diploma or Certificate best facilitated subject matter acquisition and helped them to teach mathematics better.

The professional learning activity of attending Professional Development Days was relatively frequently participated-in, but participants did not consider this learning
activity to be valuable. Furthermore, participants perceived that Professional Development Days did not facilitate subject matter acquisition as well as other learning activities considered in this study, and did not help them to teach mathematics better. Professional Development Days generally were deemed not to help NMSSTs in this study much to strengthen their mathematics content knowledge or to teach mathematics better as practicing mathematics teachers.

Half of the participants self-identified as mathematics subject specialists. Factors that influenced self-identification were years of experience teaching mathematics, teaching assignment, and perceived level of teaching expertise. Self-identification was based on how many years these teachers taught secondary mathematics, how many secondary mathematics courses they taught, and how they thought of themselves as secondary mathematics teachers. Self-identification as mathematics-subject specialists for these out-of-field teachers was based on experience, not formal training or perceived understanding of the subject matter. This contrasts with those teachers who formally trained to become secondary mathematics teachers in BC and was required to complete a minimum of 18 credits of university upper-level mathematics.

Positive correlations were also found between several NMSST characteristics. One correlation was between years of experience and age group. Another correlation was between teaching assignment and the importance of professional learning for NMSSTs. Six other relationships were found between four NMSST characteristics: years of experience, teaching assignment, perceived level of expertise, and perceived level of subject matter content knowledge. These characteristics are inter-related, which confirms the experiential learning of NMSSTs in this study; they gained subject matter content knowledge and expertise from Teaching Secondary Mathematics.

However, self-identification as mathematics subject specialists was significantly correlated to the NMSST characteristics of years of experience, teaching assignment, and perceived level of expertise. Perceived level of subject matter content knowledge was not a factor. NMSSTs in this study self-identified based on their teaching experience as secondary mathematics teachers and not subject matter preparation. Furthermore, this may be how these teachers are perceived in their school community. Most of the participants had five or more years of experience teaching secondary mathematics in BC.
schools. Even though a significant correlation could not be found using the $\chi^2$-test between years of experience and teaching assignment at $p < .05$, generally the more experience you have teaching a subject area, the more likely you will teach more of it over time. This could be confirmed at 90% confidence and with Spearman’s Rank Coefficient at $p < .05$. In this case, maybe NMSSTs who participated in this study are perceived to be the mathematics subject specialists in their school, thus they, too, self-identified as such, making subject matter preparation not as important to them, especially when they are learning the subject matter on the job.

NMSSTs in this study participated in the act of Teaching Secondary Mathematics as professional learning most frequently, perceived it to be most valuable, and believed it was very helpful in subject matter acquisition and in teaching mathematics better. Other learning activities that were frequently used, considered valuable, and believed helpful were Mathematics Textbooks, Online Resources, Mentor or Colleague, and a Master or Doctorate Degree. Professional Development Days were frequently attended but not as highly valued or deemed very helpful. Participants self-assessed their level of subject matter content knowledge and teaching expertise as proficient and self-identified as mathematics subject specialists based on experience. In the end, NMSSTs in this study were learning by doing and gained subject matter content knowledge on the job. However, the most helpful learning activity to gain subject matter content knowledge in mathematics was deemed to be completing a graduate degree in the field of mathematics education.
Chapter 6. Conclusions

Out-of-field teaching in secondary mathematics occurs in British Columbia (BC) schools where non-mathematics subject specialist teachers (NMSSTs) are assigned to teach secondary mathematics even though their formal education prior to teaching was not a major or minor in mathematics or a degree with significant mathematics. This study focused on the professional learning experiences of NMSSTs and which professional learning activities they participated in to gain subject matter content knowledge in mathematics as practicing secondary mathematics teachers. Participants also rated how well each learning activity facilitated the acquisition of the subject matter and in gaining this knowledge whether they believed it helped them to teach secondary mathematics better. Based on the literature, 16 professional learning activities were considered. These were categorized into four types of professional learning: autodidactic, learning communities, traditional professional development, and formal learning.

NMSSTs participating in this study primarily learned the subject matter on the job from Teaching Secondary Mathematics, an autodidactic learning activity. Participants generally supported this professional learning activity with other autodidactic learning activities (e.g., using a Mathematics Textbook and referring to Online Resources). Many of these participants found informal support and guidance by working with a Mentor or Colleague, an expert in the field. Both Teaching Secondary Mathematics and working with a Mentor or Colleague were considered valuable learning activities to gain subject matter knowledge in mathematics. The formal learning activity of completing a Master or Doctorate Degree was also highly valued, but few participated in this learning activity. Those participants who completed a Master or Doctorate Degree believed that completing a Master or Doctorate Degree best facilitated subject matter acquisition and in gaining that knowledge helped them to teach mathematics better.

Participants perceived their level of subject matter content knowledge in mathematics and their level of expertise as secondary mathematics teachers to be
proficient. Ninety percent (90%) of them considered their subject matter content knowledge and teaching expertise to be competent or better. This self-assessment of perceived levels of content knowledge and expertise did not differ when comparing participants who completed a Master or Doctorate Degree with those who did not. This may be due to NMSSTs without a graduate degree overestimating their mathematics understanding because they are proficient in the common content knowledge, whereas NMSSTs with a graduate degree might be underestimating their mathematics understanding because they learned more about mathematics in the context of teaching and believe there is more specialized content knowledge in mathematics to acquire.

The participants’ experience was related to self-identification as secondary mathematics subject specialists. Half of the participants self-identified as mathematics subject specialists. Factors that influenced them to self-identify were years of experience, teaching assignment, and perceived level of expertise. Their perceived level of subject matter content knowledge was not found to be a significant factor. Formally trained secondary mathematics teachers required to complete at least 18 credits of 300- and 400-level mathematics courses prior to teacher education considered subject matter preparation an important part of becoming secondary mathematics teachers. For NMSSTs in this study, it was how long they had taught secondary mathematics, how many secondary mathematics courses they taught, and how they perceived their teaching expertise as secondary mathematics teachers that mattered. Even though the NMSST characteristic of their perceived level of subject matter content knowledge was positively correlated with years of experience, teaching assignment, and perceived level of expertise, self-identification as subject specialists was based on their experience and how they might be perceived as mathematics teachers in their schools.

The NMSST participants in this survey generally come from diverse age groups, have at least five years of experience teaching secondary mathematics, teach in public schools, and may or may not self-identify as subject specialists. There was a 3:2 female ratio. More than half of their teaching assignment was in secondary mathematics. They believed professional learning for NMSSTs is important. They participated in more than one learning activity and perceived their levels of subject matter content knowledge and teaching expertise to be competent or better. Participating in professional learning activities was deemed to help these teachers to some extent in gaining subject matter
content knowledge and in teaching mathematics better. Formal learning activities were perceived to best facilitate the acquisition of the subject matter content knowledge and help these teachers to teach mathematics better whereas autodidactic learning activities were most frequently participated-in. Teaching Secondary Mathematics and completing a Master or Doctorate Degree in mathematics or related field as professional learning activities to gain subject matter content knowledge were highly valued.

The learning activities of working with Mentor or Colleague and completing a Master or Doctorate Degree were also highly valued by those who participated in these learning activities as sub-cohorts of the sample. An expert in the field facilitates learning in both of these learning activities. Working with a Mentor or Colleague was mostly informal for those who participated in this study, but was frequently participated in. Completing a Master or Doctorate Degree best facilitated the acquisition of the subject matter and helped these teachers to teach mathematics better, but was not frequently participated in. Formal learning activities require extra time, effort, and expense for teachers, whereas working with a Mentor or Colleague and other autodidactic learning activities are onsite, accessible, and convenient for teachers to participate in. On the other hand, Professional Development Days may be led by an expert in the field and frequently participated-in, but the learning activity was not highly valued by participants to gain mathematics content knowledge, and it did not rank very high in facilitating the acquisition of the subject matter or in helping them to teach secondary mathematics better. Participants did not find Professional Development Days valuable or helpful, but such days may provide other opportunities for NMSSTs to develop.

What I have learned from this study is that teachers should not learn in isolation. Even though teaching can be hectic and isolating profession, learning autodidactically is convenient and adequately satisfies the need-to-know nature of teaching out-of-field. NMSSTs highly valued the guidance and support of a mentor. Those who completed a graduate degree in mathematics education emphasized this. NMSSTs valued learning from an expert in the field. I have also learned that self-assessment of one's knowledge and one's expertise is would be challenging to achieve in isolation. Without a referent, or in this case a mentor or expert in the field, to provide some insight or wisdom on one's level of mathematics understanding, self-assessment can vary and may not reflect one's knowledge or expertise. It was not a surprise that NMSSTs in this study learned the
subject matter autodidactically. Furthermore, it was also expected that few completed a graduate degree in mathematics or mathematics related field. What was not expected was how prominent mentoring was for NMSSTs in their professional learning experience and how completing a masters or doctoral degree was highly regarded. The other surprise was self-identification as subject specialists depended on experience only.

Generally, NMSSTs learn the subject matter from experience. Some opted to complete a graduate degree in mathematics education or numeracy and retrained to become secondary mathematics specialists. Informal support from a mentor was highly valued but what qualities these experts in the field possessed to effectively induct or support the professional learning of NMSSTs is currently unknown. Another uncertainty is the role of having a formal background in mathematics or mathematics education in the development of specialized content knowledge for teaching secondary mathematics. Furthermore, experienced NMSSTs perceived their subject matter content knowledge and teaching expertise to be competent or better. It is uncertain if these teachers would be compelled or motivated to participate in further professional development to deepen their subject matter content knowledge in mathematics. However, this study adds to the literature by providing some empirical evidence that out-of-field teaching in secondary mathematics continues to exist in BC schools; substantiating that NMSSTs are learning or relearning the subject matter autodidactically; and highlighting that mentors play an important role in the professional learning experience of NMSSTs.

NMSSTs in this study generally learned the subject matter on the job from Teaching Secondary Mathematics, using Mathematics Textbooks, referring to Online Resources, or working with a Mentor or Colleague. These out-of-field teachers are learning or relearning the subject matter from experience and on the job. They are self-identifying as mathematics subject specialist teachers based on this experience and not from their perceived level of subject matter content knowledge in mathematics. Those who completed a Master or Doctorate Degree in mathematics or related field claimed to benefit from this learning activity with subject matter acquisition and improve their teaching practice in secondary mathematics. Self-assessment of subject matter content knowledge and teaching expertise in addition to self-identification might require tools or standards to help these teachers self-direct their professional learning.
6.1. Implications

There are implications for practitioners, school leaders, researchers, and policy-makers based on the findings, discussion, and conclusion. Recommendations provided are intended to help NMSSTs strengthen their mathematics content knowledge and also help them to become better secondary mathematics teachers. Implications for practitioners include finding a mentor and implementing a deliberate practice. Implications for school leaders include redesigning professional development for NMSSTs and building capacity. Implications for researchers include developing a self-assessment tool, engaging in a longitudinal study of students in graduate mathematics education programs, and investigating qualities of a mentor or experienced teacher that would best support the professional learning of NMSSTs and their acquisition of the subject matter. Implications for policy-makers include remodelling professional development opportunities for teachers and setting standards or guidelines for NMSSTs to help them self-assess their subject matter content knowledge in mathematics.

6.1.1. For practitioners.

The learning activity of Teaching Secondary Mathematics to gain subject matter content knowledge in mathematics supplemented by Mathematics Textbooks and Online Resources would be a common approach for NMSSTs teaching secondary mathematics in BC schools. They are autodidactic learning activities where the NMSST can self-direct their professional learning on a “need to know” basis. These learning activities are accessible, affordable, and convenient to use. However, some NMSSTs might end up learning the subject matter in isolation without the support or guidance from a Mentor or Colleague who may be an expert in the field. To maximize their learning, NMSSTs should seek out a mentor or colleague to work collaboratively with to deepen and broaden their understanding of the subject matter but also support their professional learning experience with encouragement, guidance, and immediate feedback.

One of the key characteristics of deliberate practice is immediate feedback (Ericsson & Pool, 2016). When teaching in a classroom or learning from a textbook or website, there is little or no opportunity to receive immediate feedback from an expert in the field. Learning in isolation does not allow NMSSTs to ask questions or experiment.
under the critical eye of a trusted and respectful colleague whose purpose is to help NMSSTs to improve and develop a deeper understanding of the subject matter. The intention of deliberate practice is to improve over time (Ericsson & Pool, 2016). In the classroom, NMSSTs may receive immediate feedback from students, but students cannot provide formative feedback on the teacher’s understanding of the subject matter because they are not experts in the field. Immediate feedback from a textbook would come from the answer key located at the back of the book or full solutions written down as examples before each section of the textbook that was designed for students to consume. Websites cannot provide personalized immediate feedback on learning unless there is direct contact with an expert in the field in real time. Otherwise, websites can provide only correct solutions or answer frequently asked questions.

A mentor or colleague can provide immediate feedback to NMSSTs on request. Working with a mentor or colleague who is an expert in the field can be a formal or informal relationship that is onsite and ongoing. It can provide subject matter specific guidance and support in the classroom or after school, as in the case of Western Australia, where experienced senior mathematics teachers mentored the junior mathematics teachers to develop their subject matter content knowledge (McConney & Price, 2009). However, not all schools or districts have formal mentorship programs to facilitate this or seasoned mathematics teachers to act as mentors. If NMSSTs are unable to find a mentor or colleague to work with locally, then they may consider participating in social media, such as Twitter, or the BC Mathematics Teachers’ Association (BCAMT) Listserv to connect with other mathematics educators in the hope of finding a viable mentor to work with.

Another opportunity for NMSSTs to learn from an expert in the field is to enrol in a formal learning activity. With more teaching experience and the likelihood of teaching more secondary mathematics courses, NMSSTs may choose to deepen their subject matter content knowledge in mathematics and change their subject specialty formally with graduate studies. This may require additional time and financial commitment, but a masters, doctorate, or diploma program in mathematics education or numeracy at a nearby university (or online) can be specifically designed for practicing mathematics teachers to gain subject matter content knowledge in the context of teaching. NMSSTs can learn from an expert in the field along with other teachers as learners who have
similar goals within a learning community. Ongoing and collaborative professional learning with an expert in the field is sustained in these university programs over a fixed period of time (e.g., 2-year program). Not all universities offer mathematics education programs and not all universities are accessible to NMSSTs living in remote areas, but there may be a possibility of online learning via a university or participating in a mathematics subject matter specific program for teachers that may be offered by universities remotely.

6.1.2. For school leadership.

To support the subject matter content knowledge development in mathematics for NMSSTs, school leaders can provide opportunities for NMSSTs to build capacity as mathematics subject specialists. NMSST characteristics of years of experience, teaching assignment, perceived level of expertise, and perceived level of subject matter content knowledge were found to be inter-related in this study, and the first three of four characteristics influenced NMSSTs in this study to self-identify as mathematics subject specialists. Based on this finding, school principals can build capacity and develop subject matter content knowledge for NMSSTs teaching in their schools by strategically constructing their teaching assignment to incorporate professional learning and mentorship.

When assigning NMSSTs to teach secondary mathematics, school principals can purposefully assign teachers in out-of-field teaching placements. In doing so, school principals can design the teaching assignment to embed subject matter development and growth as part of the NMSSTs’ professional learning. Job assignments could grow incrementally, as they did for the Chinese teachers described in Ma’s (2010) study. Moreover, NMSSTs could have an opportunity to practice by having more than one class with the same grade and content. Furthermore, the school principal can increase the number of secondary mathematics courses within the NMSST’s teaching assignment incrementally over time or increase the grade levels to familiarize the NMSSTs with Grades 8-12 mathematics.

School principals can also connect NMSSTs with a similar teaching assignment to that of an experienced mathematics teacher who is recognized in the school as an
expert in the field. The school principal can help create a formal (or informal) mentorship experience between the NMSST and experienced teacher. Moreover, the school principal can assign these teachers with the same preparation period so that the teachers can engage in ongoing, onsite, collaborative, face-to-face professional learning during the school day (Garet et al., 2001; Hill & Ball, 2004; Loucks-Horsley & Matsumoto, 1999). The school principal takes a strategic approach to developing mathematics subject specialists with NMSSTs where NMSSTs are initially identified, teaching assignments are carefully constructed, and mentorship with an expert in the field is systemically embedded. Over time, NMSSTs can then gain teaching experience and subject matter expertise.

If the NMSST chooses to transform into a mathematics subject specialist, the school principal can continue supporting him or her with annual teaching assignments and mentoring opportunities and also encourage him or her to engage in formal learning. Higher education is not accessible, flexible, or affordable for many teachers in BC. These programs are typically offered at universities located in the Lower Mainland, and teachers must commit additional time and money to complete these programs, although doing so can result in a salary increase for some teachers. To build capacity, school principals or senior management may consider incentivising formal education for NMSSTs to become mathematics subject specialists. They may offer NMSSTs part- or full-time leaves, part- or full-paid leaves, transportation assistance, subsidized tuition, or grants for learning materials. Another opportunity could be bringing a mathematics graduate diploma program to the school or district and inviting teachers from neighbouring schools to participate. School district staff can collaborate with universities to develop university credit courses or intensive summer courses with instructional coaching during the school year to support NMSSTs with their subject matter development (Papick, 2011).

School leadership also comes from those who are responsible for school- and district-based professional development days. These people may be the school principal or the teacher who is the school professional development representative or a member of a committee. Another strategy to promote ongoing collaborative professional learning for NMSSTs to develop their subject matter content knowledge is to design a subject matter focussed professional development day where out-of-field teachers can learn
from and collaborate with other NMSSTs and experts in the field as a learning community. Subject matter sessions could be offered during the day with the intention of deepening understanding of the subject matter with other NMSSTs and experts in the field. Other experts in the field can be invited to support these teachers in an ongoing basis. Subject matter focussed professional development days, carefully designed, can offer NMSSTs an ongoing, collaborative learning opportunity to learn with other NMSSTs who have similar learning needs and to connect with experts in the field as mentors.

Subject matter focussed professional development days can also incorporate formal mentorship programs that purposefully connect NMSSTs with experts in the field or integrate with initiatives the school principal may have created with formal mentorship and teaching assignments of NMSSTs. Another possibility of creating opportunities for NMSSTs to learn from experts in the field is to partner with local universities or colleges and co-create short courses for NMSSTs to participate in to gain subject matter content knowledge (Papick, 2011). Short courses rich in subject matter content could be offered throughout the school year during professional development days. Mathematics subject specialists such as university instructors or professors would facilitate these short courses as experts in the field for NMSSTs to deepen their understanding of the subject matter. This may transform understanding of the subject matter from what students should learn and understand to a level that is specialized for teaching secondary mathematics.

Further, districts could tap in to local expertise and design internal education programs to build the subject matter and teaching expertise of their staff. Creation of school wide, or cross-school learning communities of mathematics teachers, particularly if structured across feeder schools, could strengthen ongoing professional development and collaborative teaching and learning opportunities.

6.1.3. For future research.

The literature shows the existence of out-of-field teaching in schools and emphasizes the possible consequences for student achievement in mathematics (BCCT, 2001, 2004; CMEC, 2003; Ingersoll, 1999, 2001; Riordan & Hannigan, 2011; Sanders & Rivers, 1996; Wright et al., 1997). The literature also indicates that subject matter
content knowledge is necessary to develop subject-specific pedagogy and teaching expertise (Ball, 1988; Ball et al., 2005; Ball et al., 2008; Berliner, 2001, 2004; Even, 1993; Hattie, 2012; Hill & Ball, 2004; Hill et al., 2005; Krauss et al., 2008; Lachner & Nückles, 2016, Leinhardt & Smith, 1985; Ma, 2010; McConney & Price, 2009). Recommendations for future research are based on the literature and findings with the intention of informing policy makers, decision makers, and school leaders about the professional learning experiences and subject matter development of NMSSTs.

NMSSTs self-identification as mathematics subject specialists was based on their years of experience teaching secondary mathematics, teaching assignment, and perceived level of expertise as secondary mathematics teachers. Their perceived subject matter content knowledge was not a significant factor in this self-identification, which implies that subject matter preparation did not influence them to self-identify as subject specialists. Moreover, 90% of the NMSSTs participating in this study perceived their level of subject matter content knowledge and teaching expertise to be competent or better. Half perceived their content knowledge and teaching expertise as proficient. The perceived level of subject matter content knowledge in mathematics and perceived level of teaching expertise between those participants who completed a masters or doctoral degree and those who did not were the same.

Developing a self-assessment tool involves identifying experts in the field, identifying which qualities these teachers possess in terms of subject matter content knowledge and expertise, and determining what subject matter one must know and understand to teach secondary mathematics and to what extent. Such a self-assessment tool would help practicing NMSSTs determine what subject matter they know well and what content areas they need to develop, and at what depth. The tool could be implemented online and provided to NMSSTs to support them with self-directing their professional learning. Moreover, an online platform of the self-assessment tool may also provide helpful links, resources, or contact information linking NMSSTs to experts in the field and provide additional support for their professional learning. To take it a step further, a Web-based study guide could be created based on the results of the self-assessment tool that would help NMSSTs to strengthen their mathematics content knowledge online, and also provide immediate formative feedback as part of deliberate practice.
Another opportunity for future research would be investigating the subject matter content knowledge development of NMSSTs who are enrolled in a master of secondary mathematics education program and tracking their progress over time. The professional learning activity of completing a masters or doctorate degree was believed to be the best learning activity to facilitate the acquisition of subject matter content knowledge and helped these teachers to teach secondary mathematics better. This would be an exploratory longitudinal study looking at formal learning and how subject matter content knowledge influences teaching. The professional learning experiences of NMSSTs in terms of perceived level of subject matter knowledge and level of expertise before, during, and after the program could be documented. The intention of such a study would be to better understand how NMSSTs transform or deepen their mathematics understanding through formal learning that is specifically designed for secondary mathematics teachers.

Finally, working with a mentor or colleague was identified as valuable and helpful to NMSSTs in acquiring subject matter content knowledge in mathematics as practicing secondary mathematics teachers. Most of the mentoring relationships were informal. However, the nature of these relationships was not investigated further in this study. An investigation could be conducted on how these mentors or experienced colleagues support the professional learning of NMSSTs with their subject matter acquisition. What type of mentor best supports the professional learning of NMSSTs? Qualities of the mentor, years of his or her experience, and his or her subject specialty could be factors to consider in this investigation. What strategies do these mentors implement to induct NMSSTs into the practice of teaching secondary mathematics? Are these strategies effective? These are some possible questions to consider in future research when investigating qualities of mentor and his or her relationship with NMSSTs as they support and guide NMSSTs with their subject matter content knowledge development.

6.1.4. For policy-makers.

The policy that teachers certified in BC with a professional certificate can teach any grade level and any course (BC Ministry of Education, 2017a) allows for out-of-field teaching in secondary mathematics, and other subject areas, to occur in BC schools. This policy serves the employer and employee in the BC school system. As indicated in
the BC College of Teachers (2004) survey on recent graduates, there were more social studies and English teachers, for example, than there were mathematics teachers. This suggests that there was a shortage of secondary mathematics teachers in the field such that out-of-field teaching in secondary mathematics was a necessary good. The employer is required to place a teacher in every classroom every school year and conversely, teachers are looking for employment and job security. If student achievement in secondary mathematics is a priority or goal within the province, school district, or school, then policy-makers can support the professional learning of NMSSTs and their subject matter development by changing how professional development is offered and providing standards or guidelines that potential and currently practicing NMSSTs can refer to in order to self-assess their subject matter content knowledge.

Professional learning occurs best when it is ongoing, onsite, and collaborative (Garet et al., 2001; Hill & Ball, 2004; Loucks-Horsley & Matsumoto, 1999; McConney & Price, 2009). NMSSTs in this study frequently attended Professional Development Days but did not consider them valuable in strengthening their mathematics content knowledge. Professional Development Days are specific days embedded in the school year for teachers to learn something about teaching or their practice, however, Professional Development Days are not designed to be ongoing, onsite, and collaborative learning experiences. They are often structured as workshops or conferences that happen on discrete days at discrete times at schools where teachers may not teach. Given these conditions, teachers may not be able to transfer their professional learning from Professional Development Days into their practice.

Policy-makers could re-evaluate policy where Professional Development Days continue to be part of the professional learning experiences of teachers embedded throughout the school year, but the time could be distributed in a different way that would support ongoing, onsite, collaborative learning. For example, Professional Development Days could be broken into 1.5 hour increments to allow for learning blocks during the school day (that could occur every second week), allowing teachers to regularly gather together as a community of learners focused on evolving their teaching practice, ideally by working with mentors, expert teachers, or experts in the field of mathematics. Structuring Professional Development Days as ongoing professional learning would give NMSSTs an opportunity to connect and learn with other NMSSTs and experts in the field.
on a regular basis with the purpose of strengthening their mathematics content knowledge together as a collaborative group.

Another opportunity for policy-makers to support the professional learning of NMSSTs or future NMSSTs would be to provide learning standards or guidelines to help these teachers self-assess their subject matter content knowledge in mathematics and then self-direct their professional learning appropriately. This would be a self-assessment tool for NMSSTs to use and determine their level of mathematics understanding, reflect, reconceptualise how it could be different, and determine what professional learning activity or activities they could participate in to bridge that gap. Participation may entail non-traditional professional development such as a mathematics study group, a mentor, or a teacher-lab where NMSSTs can experiment and play with new ideas as a learning community with colleagues and experts in the field to get immediate feedback.

6.2. Summary

The professional learning activities NMSSTs participated in to gain subject matter content knowledge were teaching secondary mathematics, mathematics textbooks, online resources, mentor or colleague, and master or doctorate degree. Participants primarily engaged in autodidactic learning activities because they are accessible and convenient to use unlike formal learning activities that require additional time, effort, and money. Participants who worked with a Mentor or Colleague or completed a Master or Doctorate degree valued these learning activities over Teaching Secondary Mathematics. Participants believed that completing a formal Masters or Doctorate Degree best facilitated subject matter acquisition and helped them to teach secondary mathematics better. Their perceived levels of subject matter content knowledge and teaching expertise were proficient. NMSST characteristics that influenced participants in the self-identification as subject specialists were years of experience, teaching assignment, and perceived level of expertise. Recommendations were made to the practitioner, school leadership, researchers, and policy-makers.
Practitioners are encouraged not to learn in isolation and to find a mentor to work and learn with. Autodidactic learning activities are convenient to use, particularly when learning the subject matter on the job, but working with an expert in the field as ongoing collaborative professional development deepens subject matter content knowledge over time with deliberate practice and immediate feedback. School principals are encouraged to assign NMSSTs mathematics courses where the content is relatively easy to acquire and in multiple sections to practice. The teaching assignment could also be similar to one that another experienced secondary mathematics teacher is teaching. The more-experienced teacher could act as a mentor and possibility share the same preparation block so the two teachers could collaborate and learn together. School leaders responsible for designing professional development days can support this formal mentoring with subject matter focussed professional development where NMSSTs can come together, form a learning community, and learn with other NMSSTs and experts in the field. Professional development days could facilitate subject matter specific sessions by collaborating with a university or college to co-create short courses during these days, university credit courses, or summer intensive courses. Recommendations for future research include creating a self-assessment tool for NMSSTs that would help them to determine their level of subject matter knowledge and identify areas they need to work on. Another area for research would be investigating the subject matter content knowledge acquisition of NMSSTs enrolled in a master program in secondary mathematics education over time. Policy-makers could reconstruct Professional Development Days to model and encourage ongoing, onsite collaborative learning amongst peers and provide standards or guidelines for NMSSTs to self-assess their mathematics content knowledge and help self-direct their professional learning.

Participating in professional learning activities was deemed to have helped NMSSTs in this study to strengthen their subject matter content knowledge and to become better secondary mathematics teachers to some extent. These teachers tended to learn the subject matter autonomously, but valued the support and guidance of an expert in the field. Participants had at least 5 years of teaching experience and perceived their subject matter content knowledge and teaching expertise to be competent or better as secondary mathematics teachers. These teachers may know only the subject matter that students should learn and not the specialized content knowledge that a secondary mathematics teacher should know. Thus, a self-assessment
tool would be helpful to NMSSTs to self-direct their professional learning. They can also seek the support and guidance from a mentor who is an expert in the field. The opportunity to embed professional learning within the NMSST’s job assignment with courses, preparation time, and mentorship can further assist out-of-field teachers to gain subject matter content knowledge from deliberate practice and work experience. Moreover, NMSSTs may engage in graduate studies and pursue a master degree in secondary mathematics education to change their subject speciality with formal learning and also deepen their understanding of the subject matter with experts in the field and the learning community of fellow classmates and colleagues.

Strengthening the subject matter knowledge and teaching skills of NMSSTs is a complex and potentially costly endeavour. That said, investment in their learning and helping teachers be more successful in the classroom is likely to have a significant impact on student learning, long term employment satisfaction, and over all school and district success. While this thesis cannot build a roadmap for change, I sincerely hope that the information presented here will inform teachers interested in strengthening their subject matter knowledge and teaching skills; district leaders interested in improving teaching and professional development in their schools; and researchers interested in better understanding the approaches out-of-field teachers take toward strengthening their subject matter knowledge.
References


Appendix A. Letter to Participate in the Study

Email Subject: Looking for your participation

Greetings fellow math educators…

I am a graduate student at Simon Fraser University in the doctorate program of Educational Leadership. I am conducting a study looking at the professional learning experiences of non-mathematics-subject-specialist teachers who teach secondary mathematics in BC schools. These teachers are certified to teach in BC schools and entered the teaching profession with subject preparation not in mathematics.

I am looking for participants to partake in my survey questionnaire that will ask these non-mathematics-subject-specialist teachers on what professional learning activities they have participated in to strengthen their mathematics content knowledge as practicing secondary mathematics teachers in BC schools. The survey will take approximately 5 to 20 minutes to complete. Your participation or assistance would be greatly appreciated.

If you have taught or currently teach in BC schools, did not complete a degree with a major or minor in mathematics or one with significant mathematics content prior to teaching, and have taught or currently teaching secondary mathematics in BC schools you are a candidate to participate in this survey. If this is not you, please forward this invitation to a colleague or colleagues who may satisfy this participant profile.

The purpose of this study is to investigate the learning experiences of non-mathematics-subject-specialist teachers and gather pertinent information that would shed light on what professional learning activities would best support teachers who are teaching secondary mathematics out-of-field with their mathematics content knowledge development.

Although email and social media are not confidential mediums, your participation in the online survey questionnaire will be confidential and information provided anonymous. For more information, proceed with the survey and read further in the informed consent.

I would also encourage you to forward this invitation to other teachers and math educators in BC who may be viable candidates to participate in this survey questionnaire. If you have any questions, please do not hesitate to contact me, the principal investigator, via phone [personal info omitted] or email [personal info omitted]. For more information regarding the study, go to www.christineyounghusband.com/research.

Thank you for your consideration. If you would like to participate, go to the survey link at https://www.surveymonkey.com/r/NMSSTsurvey. Your time, input, and insight on your professional learning experiences are welcomed, valued, and respected.

Warm regards,
Christine Younghusband
Graduate Student, Simon Fraser University
Appendix B. Letter to Participate in Pilot Test 1

Hello...

Thank you for agreeing to participate in piloting my survey for my doctoral research. Your time, expertise, and feedback are greatly appreciated. If you are unable to participate, please let me know. As Phase 1 of my pilot process, I approached 5 BCAMT Executive members to review my online survey to determine face validity and get your input on how to improve this survey questionnaire in the areas of clarity, appropriateness, flow, and non-bias. The feedback form is attached. Please follow the following instructions. If you have any questions before or after taking the survey, do not hesitate to ask to get any clarification or guidance you may require.

Purpose of the Survey

This survey is part of a descriptive research study, as part of a dissertation project completed under the auspices of Simon Fraser University, which will investigate the professional learning experiences of non-mathematics-subject-specialist teachers who have taught or currently teach secondary mathematics (Grades 8-12) in BC schools. This study hopes to identify which professional learning activities these teachers participate in to gain their subject matter content knowledge in mathematics, which activities they preferred, and which helped them to be better secondary mathematics teachers. The purpose of this study is to collect pertinent information that may inform other non-specialist teachers, school-based leaders, and district level decision-makers as to how to best support the professional learning of non-mathematics-subject-specialist teachers who teach secondary mathematics in BC schools with respect to their mathematics content knowledge development. Thank you for participating in the pilot test of the survey to provide some feedback based on your understanding and perception of the survey items. Results from the pilot tests will not be included in the study.

Instructions

1. Please record the time it takes you to complete the survey.

2. Please complete the survey as if you are a non-mathematics-subject-specialist teacher (NMSST) who teaches secondary mathematics. In this study, NMSST is defined as a certified teacher who did not complete a minor or major in mathematics or a degree with significant mathematics prior to entering the teaching profession. Furthermore, NMSST teach or have taught one or more secondary mathematics courses in BC Schools during their teaching career.

3. Please answer the questions to the best of your ability. You may also have a person in mind as you take the survey, if that is helpful to you. To re-enact the experience of a survey participant, you will not allowed ask me any questions during the survey. Link to the survey: https://www.surveymonkey.com/s/BCAMTpilot

4. After the survey, please fill out the feedback form attached. Email your completed feedback form to Christine Younghusband at [personal information omitted].
include your phone number. You may be called for an interview to establish any clarification on what has been submitted.

5. With your email, please comment on the following questions regarding the survey:

The approximate time it took to complete the online survey.

What message did the survey send? What was the survey about?

Will the survey achieve what is set out to achieve? Why or why not?

How can this survey be improved? These are additional comments to feedback form.

6. Revisions will be made to the survey based on the feedback provided from the first phase of the pilot. You will receive a link to the newly revised survey to check if the survey has incorporated the feedback appropriately. There will be a second pilot conducted with a group of NMSST.

7. Agreement from the two pilot groups will finalize the online survey.

8. THANK YOU AGAIN for taking the time to help out with this study. Greatly appreciated. I look forward to your feedback and moving forward with my study.

Warm regards,
Christine
Appendix C. Pilot Test Feedback Form

Feedback Form

Thank you for your participation in the pilot test of this survey questionnaire. Highlight "yes" or "no" for each characteristic for each section. If you answer "no" on any of the following characteristics, please explain your answer further in the comment section.

**Clarity**: Were the items in this section clear and understandable? Did you understand what the questions were asking for in this section? Were the meanings of the questions in this section straightforward?

**Appropriateness**: Were the scales adequate in this section? Was there enough opportunity to respond to the questions in this section?

**Flow**: Did the questions in each section follow a natural or logical flow? Were there any questions in each section that seemed out of place?

**Non-Bias**: Were questions in this section unbiased or not obvious? Were the questions worded in such a way that did not sway your response?

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<th>Appropriateness</th>
<th>Flow</th>
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<td>Other Formal Learning Activities</td>
<td>Yes or No</td>
<td>Yes or No</td>
<td>Yes or No</td>
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<td>Section</td>
<td>Clarity</td>
<td>Appropriateness</td>
<td>Flow</td>
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<td>Other Professional Learning Activities</td>
<td>Yes or No</td>
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<td>Preferred Learning Activity</td>
<td>Yes or No</td>
<td>Yes or No</td>
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<tr>
<td>Background Information</td>
<td>Yes or No</td>
<td>Yes or No</td>
<td>Yes or No</td>
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Appendix D. Letter to Participate in Pilot Test 2

Hi…

Thank you for agreeing to participate in the second phase of the pilot test for my survey questionnaire involving non-mathematics-subject-specialist teachers for my doctoral research. Your time, expertise, and feedback are greatly appreciated. If you are unable to participate, please let me know.

Phase 1 of the pilot process has been completed and the survey questionnaire has been revised based on feedback. This first phase involved 5 BC Association of Mathematics Teachers (BCAMT) Executive Committee members who completed online survey to determine its face validity and provided feedback to improve the survey in the areas of clarity, appropriateness, flow, and non-bias.

Phase 2 will involve the same 5 BCAMT participants in addition to 8 non-mathematics-subject-specialist teacher (NMSST) participants. The BCAMT participants will review the changes made to the survey and the NMSST participants will provide feedback on the newly revised survey questionnaire.

The feedback form is attached. Furthermore, a PDF version of the survey questionnaire is also attached to this email. Please do not preview the PDF until you have completed the online survey questionnaire. Use the PDF only as a reference as you complete the feedback form.

The purpose of the study is included in the preamble of the survey questionnaire. Results from the pilot tests will not be included in the final study. However, the data collected will be used to formulate the data analysis plan for the study. Follow the instructions below. If you have any questions before or after taking the survey, please do not hesitate to ask to get any clarification you may require.

Instructions

1. Please record the time it takes you to complete the survey. The entire pilot process, aka completion of the survey and feedback form, should take no longer than 40 minutes.

2. For the 5 BCAMT returning participants, please complete the survey as if you are a non-mathematics-subject-specialist teacher (NMSST), as you did in Phase 1. For the 8 NMSST newly participating in Phase 2, please complete the survey as if you are a participant of the study.

3. Please answer the questions to the best of your ability. To re-enact the experience of a survey participant, please ask me any questions before or after the survey. Here is the link to the online survey questionnaire: https://www.surveymonkey.com/s/NMSSTpilot

4. After completing the survey, please fill out the feedback form attached to this email. Email your completed feedback form to Christine Younghusband. Please include
your phone number. You may be called for an interview to establish any clarification on what has been submitted.

I hope you are all enjoying the start of your summer holidays. I realize that this may not be the best time, but I am overwhelmed with gratitude. Thank you, once again. I look forward to your participation and feedback. Please complete the survey and feedback form by **Wednesday, July 15, 2015**.

Warm regards,
Christine

Please reply to email to confirm receipt.

Thank You!!!
Appendix E.  Certificate of Completion of Research Involving Humans Course on Research Ethics

Certificate of Completion

This document certifies that

Alice Christine Younghusband

has completed the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans Course on Research Ethics (TCPS 2: CORE)

Date of Issue: 12 July, 2015
Appendix F. Survey Instrument

The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Welcome to My Survey - Application Number 2013s0444

Dear Participant:

Thank you for participating in this survey questionnaire looking at the professional learning experiences of non-mathematics subject specialist teachers in British Columbia (BC) schools. Your participation is greatly appreciated. This online survey will take approximately 5 to 20 minutes to complete.

STUDY TEAM
Principal Investigator:
Christine Younghusband, Doctor of Education Candidate in Educational Leadership, Simon Fraser University, Phone: 604-741-3876, Email: ach10@sfu.ca

Senior Supervisor:
Dan Laitsch, Associate Professor, Faculty of Education, Simon Fraser University, Phone: 778-782-3196, Email: dlaitsch@sfu.ca

INVITATION AND STUDY PURPOSE
I am interested in the professional learning experiences of non-mathematics subject specialist teachers who teach secondary mathematics (grades 8-12) in BC schools. These teachers did not complete a degree with a major or minor in mathematics or one with significant mathematics content, such as engineering or physics, prior to entering the teaching profession in BC schools, yet they are assigned to teach one or more classes of secondary mathematics. It is exactly this phenomenon that I am interested in and what professional learning activities these teachers participate in to strengthen their knowledge of mathematics to teach secondary mathematics. Professional learning activities may include reading a book, working with a colleague, attending a workshop, or formal coursework. As such, I am hoping you will participate in this survey questionnaire to identify these professional learning activities, which learning activities you preferred, and which helped you to become better at teaching mathematics.

The purpose of this study is to collect pertinent information that may inform teacher leaders, school principals, or district level decision-makers as to how to best support the professional learning of non-mathematics subject specialist teachers who teach secondary mathematics in BC
schools with respect to their mathematics content knowledge development. This is a descriptive research study as part of my dissertation project to be completed under the auspices of Simon Fraser University.

**VOLUNTARY PARTICIPATION**
Your participation is voluntary. Should you choose to participate, you can withdraw from the study at any time without consequences. This can be achieved by closing the window on your browser before submitting your responses. However, once your data is submitted, this data cannot be removed because your participation will be anonymous (see below).
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Welcome to My Survey - continued - Application Number 2013s0444

STUDY PROCEDURES
As part of this study, you will be asked to complete this online survey, but also forward the survey link with the Letter of Invitation to other teachers who may satisfy the participant profile: a certified non-mathematics subject specialist teacher who has taught at least one secondary mathematics course in a BC school, and participated in some professional learning in mathematics. This is part of the convenience sampling process. You can forward the Letter of Invitation by email or social media such as Facebook or Twitter. The Letter of Invitation will also be posted and shared on the BC Association of Mathematics Teachers Listserv. Participants must be adults 19 years of age or older.

Data will only be collected from those who give informed consent (see Questions 1 and 2). If you say ‘yes’ to both questions, you will be asked various questions in the online survey questionnaire about your professional learning experiences in strengthening your mathematics subject matter knowledge. Your participation and assistance to distribute this survey are greatly appreciated. Information regarding this study can be found on my website at www.christineyoughusband.com/research. Survey participation for this study will be available from November 23 to December 6, 2015.

POTENTIAL RISK OF THE STUDY
No perceived harm, mental or physical, is anticipated. Minimal risk is expected. Your participation in this study will remain anonymous. The data collected will not be coded, thus the link between the data provided and the participant is irrevocably broken. You are being contacted as an individual teacher, not as a member of your school, school district, or representative of your organization, thus no ethics approval from them was requested.

POTENTIAL BENEFITS OF THE STUDY
There are no potential benefits from participating in this research with exception to the possibility of providing information that may inform decision makers in BC schools on which professional learning activities would strengthen subject matter content knowledge in mathematics for NMSST. No remuneration will be provided in this study.

DISSEMINATION OF RESULTS
Aggregated results will be reported and summarized in the dissertation, which will be made available in the SFU Library. The final draft of the dissertation will also be made available at www.christineyounghusband.com/research, the principal investigator’s website. Research results will be transmitted in the following ways: (1) results will be shared with school districts, independent schools, and provincial education related organizations (as requested); (2) papers will be submitted for publication and research conferences; (3) practitioner-focused articles will be submitted to professional magazines, journals, and newsletters; and (4) session proposals will be submitted and, if accepted, presented at professional conferences.
CONFIDENTIALITY
Participation is voluntary and responses will be kept anonymous. Only the principal investigator will have access to the survey data and no survey can be linked to your school or individual teacher. Data collected in this study will remain anonymous and confidential. Data will be password protected at all times. Although no computer transmission can be perfectly secure, all reasonable efforts will be made to protect the confidentiality of your submission [1]. Data will be kept in storage for 2-years in a password-protected file on a password-protected computer after the completion of this dissertation, then destroyed. Furthermore, data will be reported out in the aggregate to ensure your confidentiality.

Contact Information Regarding Study Procedures and Results:
If you have any questions about the study, please contact the principal investigator, Christine Younghusband, Graduate Student, Faculty of Education, Simon Fraser University, 604-741-3876 or ach10@sfu.ca.

Contact Information Regarding Rights of Research Participants:
If you have any concerns regarding the study, please direct them to: Dr. Jeff Toward, Director, Office of Research Ethics, Simon Fraser University, 778-782-6593, jtoward@sfu.ca, Application Number [2013s0444].

SURVEY STRUCTURE
As you proceed with the survey, please note that the survey is divided into 8 sections:

1. Informed Consent and Participant Profile
2. Autodidactic (or self-taught) Learning Activities
3. Learning Communities as Professional Learning
4. Traditional Professional Development
5. Formal Professional Learning Activities
6. Other Professional Learning Activities
7. Preferred Professional Learning Activities
8. Background Information
Thank you for your consideration and participation in this research study. The survey questionnaire will begin on the next page.

[1] Please note that Survey Monkey operates under the provisions of the US Patriot Act where US authorities may access any information without disclosing that the information has been accessed. However, information acquired during this research study does not contain any sensitive material and steps have been taken to de-identify the data. By responding 'yes' to both questions 1 and 2 in the survey questionnaire, you have provided informed consent to participate in this study and your responses to be transferred to a server outside of Canada.
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Section 1: Informed Consent

In this descriptive research study, the principal investigator is interested in your mathematics content knowledge development, not pedagogy. The survey looks at the professional learning activities you undertook to improve your knowledge of mathematics as a secondary mathematics teacher in BC schools. Questions 1 and 2 are asking for your informed consent to participate.

1. Have you read the information provided and understand what is being requested of you as a participant?
   - [ ] Yes
   - [ ] No

2. Do you agree to participate in this study?
   - [ ] Yes
   - [ ] No
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Section 1: Participant Profile

The following questions will determine if you satisfy the participant profile of a "non-mathematics subject specialist teacher" practicing in BC schools and whether or not you will proceed with the rest of the survey.

3. Have you taught or do you currently teach in British Columbia (BC) schools?
   - Yes
   - No

4. Have you taught or do you currently teach at least one secondary mathematics class (grades 8-12) in BC schools?
   - Yes
   - No

5. Before teaching in BC schools, did you complete a degree with a major in mathematics, minor in mathematics, or one with significant mathematics content such as engineering or physics?
   - Yes
   - No

6. How important is it for you to participate in professional learning activities to strengthen your knowledge of mathematics as a practicing secondary mathematics teacher in BC schools?

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<tr>
<th>Very important</th>
<th>Important</th>
<th>Somewhat important</th>
<th>Not important</th>
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152
7. Have you attempted to improve your knowledge of mathematics during your teaching career in BC schools?

- Yes
- No
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers:
A Descriptive Study

Completed a degree with significant mathematics

You have answered “yes” to question 5 in the Participant Profile. Please share with us what undergraduate or graduate degree(s) you have completed in the field of mathematics prior to entering the teaching profession in BC schools.

8. What undergraduate or graduate degree(s) with significant mathematics content did you complete prior to entering the teaching profession in BC schools? Please list below.

Degree 1: 
Degree 2: 
Degree 3: 
Degree 4: 
Degree 5: 

The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Section 2: Autodidactic Learning Activities #1

In this section, the following questions will ask you about any autodidactic (or self-taught) learning activities you may have participated in to improve your knowledge of mathematics as a practicing secondary mathematics teacher in BC schools.

9. Did you use mathematics textbooks to gain your mathematics content knowledge?

☐ Yes
☐ No
☐ Skip this question
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Autodidactic Learning Activity - Mathematics Textbooks

The following questions refer to using "mathematics textbooks" to improve your knowledge of mathematics.

10. To what extent did learning mathematics from mathematics textbooks help you strengthen your knowledge of mathematics?

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<tr>
<th>To a great extent</th>
<th>Some extent</th>
<th>Very little</th>
<th>Not at all</th>
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</table>

11. To what extent do you feel learning mathematics from mathematics textbooks helped you to become a better mathematics teacher?

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<tr>
<th>To a great extent</th>
<th>Some extent</th>
<th>Very little</th>
<th>Not at all</th>
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The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Section 2: Autodidactic Learning Activities #2

In this section, the following questions will ask you about any autodidactic (or self-taught) learning activities you may have participated in to improve your knowledge of mathematics as a practicing secondary mathematics teacher in BC schools.

12. Did you use books about mathematics to gain your mathematics content knowledge?
   - [ ] Yes
   - [ ] No
   - [ ] Skip this question
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Autodidactic Learning Activity - Books About Mathematics

The following questions refer to using "books about mathematics" to improve your knowledge of mathematics.

13. To what extent did learning mathematics from books about mathematics help you strengthen your knowledge of mathematics?

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<th>To a great extent</th>
<th>Some extent</th>
<th>Very little</th>
<th>Not at all</th>
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</table>

14. To what extent do you feel learning mathematics from books about mathematics helped you to be a better secondary mathematics teacher?

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<thead>
<tr>
<th>To a great extent</th>
<th>Some extent</th>
<th>Very little</th>
<th>Not at all</th>
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</table>
In this section, the following questions will ask you about any autodidactic (or self-taught) learning activities you may have participated in to improve your knowledge of mathematics as a practicing secondary mathematics teacher in BC schools.

15. Did teaching secondary mathematics help you gain your mathematics content knowledge?
   ○ Yes
   ○ No
   ○ Skip this question
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Autodidactic Learning Activity - Teaching Secondary Mathematics

The following questions refer to the act of "teaching secondary mathematics" to improve your knowledge of mathematics.

16. To what extent did teaching secondary mathematics help you strengthen your knowledge of mathematics?

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<th>To a great extent</th>
<th>Some extent</th>
<th>Very little</th>
<th>Not at all</th>
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17. To what extent do you feel teaching secondary mathematics helped you to be a better secondary mathematics teacher?

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<thead>
<tr>
<th>To a great extent</th>
<th>Some extent</th>
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<th>Not at all</th>
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The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Section 2: Autodidactic Learning Activities #4

In this section, the following questions will ask you about any autodidactic (or self-taught) learning activities you may have participated in to improve your knowledge of mathematics as a practicing secondary mathematics teacher in BC schools.

18. Did you use online resources to gain your mathematics content knowledge?
   - [ ] Yes
   - [ ] No
   - [ ] Skip this question
The following questions refer to using "online resources" to improve your knowledge of mathematics.

19. Which online resources did you use to improve your mathematics content knowledge? Please list below.

<table>
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<tr>
<th>Online Resource 1:</th>
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<tr>
<th>Online Resource 2:</th>
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<th>Online Resource 3:</th>
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<th>Online Resource 4:</th>
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<tr>
<th>Online Resource 5:</th>
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</table>

20. To what extent did learning mathematics online help you strengthen your knowledge of mathematics?

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<th>Some extent</th>
<th>Very little</th>
<th>Not at all</th>
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</table>

21. To what extent do you feel learning mathematics online helped you to be a better secondary mathematics teacher?

<table>
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<tr>
<th>To a great extent</th>
<th>Some extent</th>
<th>Very little</th>
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The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Section 2: Other Autodidactic Learning Activities

In this section, you have considered the following autodidactic learning activities to improve your knowledge of mathematics:
- learning from a mathematics textbook
- books about mathematics
- teaching secondary mathematics
- online resources

22. Did you participate in any other autodidactic (or self-taught) learning activities, not yet considered in this survey, to improve your mathematics content knowledge?

- Yes
- No
- Skip this question
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Autodidactic Learning Activity - Other

In this section, you have considered the following autodidactic learning activities to improve your knowledge of mathematics:
- learning from a mathematics textbook
- books about mathematics
- teaching secondary mathematics
- online resources

23. What other types of autodidactic (or self-taught) learning activities did you participate in, not yet considered in this survey, to improve your mathematics content knowledge? Briefly describe each learning activity and list below.

Autodidactic Activity 1: 

Autodidactic Activity 2: 

Autodidactic Activity 3: 

Autodidactic Activity 4: 

Autodidactic Activity 5: 

Section 3: Learning Communities as Professional Learning #1

In this section, the following questions will ask you about any learning communities as professional learning you may have participated in to improve your knowledge of mathematics as a practicing secondary mathematics teacher in BC schools.

24. Did you participate in school or district supported learning communities to gain your mathematics content knowledge?

☐ Yes
☐ No
☐ Skip this question
# The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

## Learning Communities - School or District Supported

The following questions refer to using "school or district supported learning communities" to improve your knowledge of mathematics.

25. To what extent did participating in school or district supported learning communities help you strengthen your knowledge of mathematics?

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26. To what extent do you feel participating in school or district supported learning communities helped you to be a better secondary mathematics teacher?

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<th>To a great extent</th>
<th>Some extent</th>
<th>Very little</th>
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The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Section 3: Learning Communities as Professional Learning #2

In this section, the following questions will ask you about any learning communities as professional learning you may have participated in to improve your knowledge of mathematics as a practicing secondary mathematics teacher in BC schools.

27. Did a mentor or colleague help you gain your mathematics content knowledge?

☐ Yes
☐ No
☐ Skip this question
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers:
A Descriptive Study

Learning Communities - Mentor or Colleague

The following questions refer to learning from a "mentor or colleague" to improve your knowledge
of mathematics.

28. Was your mentor or colleague part of a formal district sponsored program?
   ○ Yes
   ○ No

29. To what extent did your mentor or colleague help you strengthen your knowledge of mathematics?

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30. To what extent do you feel your mentor or colleague helped you to be a better secondary mathematics
teacher?

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The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Section 3: Learning Communities as Professional Learning #3

In this section, the following questions will ask you about any learning communities as professional learning you may have participated in to improve your knowledge of mathematics as a practicing secondary mathematics teacher in BC schools.

31. Did participating in mathematics study or reading groups help you gain your mathematics content knowledge?

☐ Yes
☐ No
☐ Skip this question
Learning Communities - Mathematics Study or Reading Groups

The following questions refer to using "mathematics study or reading groups" to improve your knowledge of mathematics.

32. To what extent did participating in mathematics study or reading groups help you strengthen your knowledge of mathematics?

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<th>A great extent</th>
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33. To what extent do you feel participating in mathematics study or reading groups helped you to be a better secondary mathematics teacher?

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Section 3: Learning Communities as Professional Learning #4

In this section, the following questions will ask you about any learning communities as professional learning you may have participated in to improve your knowledge of mathematics as a practicing secondary mathematics teacher in BC schools.

34. Did participating in social media or listserves help you gain your mathematics content knowledge?

- [ ] Yes
- [ ] No
- [ ] Skip this question
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Learning Communities - Social Media or Listserves

The following questions refer to using "social media or listserves" to improve your knowledge of mathematics.

35. To what extent did participating in social media or listserves help you strengthen your knowledge of mathematics?

   
   
   To a great extent
   Some extent
   Very little
   Not at all

36. To what extent do you feel participating in social media or listserves helped you to be a better secondary mathematics teacher?

   
   
   To a great extent
   Some extent
   Very little
   Not at all
In this section, you have considered the following learning communities to improve your knowledge of mathematics:
- school or district supported learning communities
- mentor or colleague
- mathematics study or reading groups
- social media or listserves

37. Did you participate in any other learning communities, not mentioned above, to improve your mathematics content knowledge?

- Yes
- No
- Skip this question
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Learning Communities as Professional Learning - Other

In this section, you have considered the following learning communities to improve your knowledge of mathematics:
- school or district supported learning communities
- mentor or colleague
- mathematics study or reading groups
- social media or listserves

38. What other types of learning communities did you participate in, not yet mentioned, to improve your mathematics content knowledge? Briefly describe each learning community and list below.

Learning Community 1: 
Learning Community 2: 
Learning Community 3: 
Learning Community 4: 
Learning Community 5: 

174
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Section 4: Traditional Professional Development #1

In this section, the questions will ask you about traditional professional development you may have participated in to improve your knowledge of mathematics as a practicing secondary mathematics teacher in BC schools.

39. Did you attend provincial or national conferences to gain your mathematics content knowledge?

- [ ] Yes
- [ ] No
- [ ] Skip this question
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Traditional Professional Development - National or Provincial Conferences

The following questions refer to attending "provincial or national conferences" to improve your knowledge of mathematics.

40. To what extent did attending these provincial or national conferences help you strengthen your knowledge of mathematics?

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<th>To a great extent</th>
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</tbody>
</table>

41. To what extent do you feel attending provincial or national conferences helped you to be a better secondary mathematics teacher?

<table>
<thead>
<tr>
<th>To a great extent</th>
<th>Some extent</th>
<th>Very little</th>
<th>Not at all</th>
</tr>
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<tbody>
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</tbody>
</table>
Section 4: Traditional Professional Development #2

In this section, the questions will ask you about traditional professional development you may have participated in to improve your knowledge of mathematics as a practicing secondary mathematics teacher in BC schools.

42. Did you attend school or district professional development days to gain your mathematics content knowledge?

- [ ] Yes
- [ ] No
- [ ] Skip this question
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Traditional Professional Development: School or District Pro-D Days

The following questions refer to attending "school or district professional development days" to improve your knowledge of mathematics.

43. To what extent did attending these school or district professional development days help you strengthen your knowledge of mathematics?

<table>
<thead>
<tr>
<th>To a great extent</th>
<th>Some extent</th>
<th>Very little</th>
<th>Not at all</th>
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<td></td>
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</table>

44. To what extent do you feel attending school or district professional development days helped you to be a better secondary mathematics teacher?

<table>
<thead>
<tr>
<th>To a great extent</th>
<th>Some extent</th>
<th>Very little</th>
<th>Not at all</th>
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</table>
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Section 4: Traditional Professional Development #3

In this section, the questions will ask you about traditional professional development you may have participated in to improve your knowledge of mathematics as a practicing secondary mathematics teacher in BC schools.

45. Did you attend administration initiated inservice workshops to gain your mathematics content knowledge?

☐ Yes
☐ No
☐ Skip this question
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Traditional Professional Development - Administration Initiated Inservice Workshops

The following questions refer to attending “administration initiated inservice workshops” to improve your knowledge of mathematics.

46. To what extent did attending administration initiated inservice workshops help you strengthen your knowledge of mathematics?

<table>
<thead>
<tr>
<th>To a great extent</th>
<th>Some extent</th>
<th>Very little</th>
<th>Not at all</th>
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</tbody>
</table>

47. To what extent do you feel attending administration initiated inservice workshops helped you to be a better secondary mathematics teacher?

<table>
<thead>
<tr>
<th>To a great extent</th>
<th>Some extent</th>
<th>Very little</th>
<th>Not at all</th>
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</table>
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Section 4: Traditional Professional Development #4

In this section, the questions will ask you about traditional professional development you may have participated in to improve your knowledge of mathematics as a practicing secondary mathematics teacher in BC schools.

48. Did you attend a continuing studies, non-credit workshop at a university or college to gain your mathematics content knowledge?

- Yes
- No
- Skip this question
The following questions refer to attending "continuing studies, non-credit workshops" to improve your knowledge of mathematics.

49. To what extent did attending a continuing studies, non-credit workshop at a university or college help you strengthen your knowledge of mathematics?

<table>
<thead>
<tr>
<th>To a great extent</th>
<th>Some extent</th>
<th>Very little</th>
<th>Not at all</th>
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<tbody>
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<td></td>
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</table>

50. To what extent do you feel attending a continuing education, non-credit workshop helped you to be a better secondary mathematics teacher?

<table>
<thead>
<tr>
<th>To a great extent</th>
<th>Some extent</th>
<th>Very little</th>
<th>Not at all</th>
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</table>
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Section 4: Other Traditional Professional Development

In this section, you have considered the following traditional professional development to improve your knowledge of mathematics:
- provincial or national conferences
- school or district professional development days
- administration initiated inservice workshops
- non-credit continuing studies workshops

51. Did you participate in any other professional development, not mentioned above, to improve your mathematics content knowledge?

☐ Yes
☐ No
☐ Skip this question
In this section, you have considered the following traditional professional development to improve your knowledge of mathematics:
- provincial or national conferences
- school or district professional development days
- administration initiated inservice workshops
- non-credit continuing studies workshops

52. What other types of traditional professional development did you participate in, not yet mentioned, to improve your mathematics content knowledge? Briefly describe each professional development event and list below.

<table>
<thead>
<tr>
<th>Professional Development</th>
<th></th>
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<tbody>
<tr>
<td>1:</td>
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<tr>
<td>2:</td>
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<tr>
<td>3:</td>
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<tr>
<td>4:</td>
<td>--</td>
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<tr>
<td>5:</td>
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</tbody>
</table>
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Section 5: Formal Professional Learning Activities #1

In this section, the questions will ask you about any formal professional learning activities you may have participated in to improve your knowledge of mathematics as a practicing secondary mathematics teacher in BC schools.

53. While you were teaching, did you learn your mathematics content knowledge by completing a master or doctorate degree in mathematics or graduate degree with significant mathematics content?

☐ Yes
☐ No
☐ Skip this question
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Master or Doctorate Degree in Mathematics or One With Significant Mathematics Content

The following questions refer to enrolling in a "master or doctorate degree program in mathematics or one with significant mathematics content" to improve your knowledge of mathematics.

54. Which graduate degree(s) in mathematics or mathematics related did you complete? Please list below.

Graduate Degree 1: 
Graduate Degree 2: 
Graduate Degree 3: 

55. To what extent did completing a graduate degree in mathematics or related field help you strengthen your knowledge of mathematics?

<table>
<thead>
<tr>
<th>To a great extent</th>
<th>Some extent</th>
<th>Very little</th>
<th>Not at all</th>
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</table>

56. To what extent do you feel completing a graduate degree in mathematics or related field helped you to be a better secondary mathematics teacher?

<table>
<thead>
<tr>
<th>To a great extent</th>
<th>Some extent</th>
<th>Very little</th>
<th>Not at all</th>
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</tbody>
</table>
Section 5: Formal Professional Learning Activities #2

In this section, the questions will ask you about any formal professional learning activities you may have participated in to improve your knowledge of mathematics as a practicing secondary mathematics teacher in BC schools.

57. While you were teaching, did you learn your mathematics content knowledge by completing an undergraduate degree in mathematics or undergraduate degree with significant mathematics content?

- [ ] Yes
- [ ] No
- [ ] Skip this question
The following questions refer to enrolling in an "undergraduate degree program in mathematics or one with significant mathematics content" to improve your knowledge of mathematics.

58. Which undergraduate degree(s) in mathematics or mathematics related did you complete? Please list below.

Undergraduate Degree 1: 

Undergraduate Degree 2: 

Undergraduate Degree 3: 

59. To what extent did completing an undergraduate degree in mathematics or related field while you were teaching secondary mathematics help you strengthen your knowledge of mathematics?

<table>
<thead>
<tr>
<th>To a great extent</th>
<th>Some extent</th>
<th>Very little</th>
<th>Not at all</th>
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</tbody>
</table>

60. To what extent do you feel completing an undergraduate degree in mathematics or related field while you were teaching secondary mathematics helped you to be a better secondary mathematics teacher?

<table>
<thead>
<tr>
<th>To a great extent</th>
<th>Some extent</th>
<th>Very little</th>
<th>Not at all</th>
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</tbody>
</table>
In this section, the questions will ask you about any formal professional learning activities you may have participated in to improve your knowledge of mathematics as a practicing secondary mathematics teacher in BC schools.

61. While you were teaching, did you learn your mathematics content knowledge by completing a diploma or certificate with significant mathematics content?

- [ ] Yes
- [ ] No
- [ ] Skip this question
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Diploma or Certificate with Significant Mathematics Content

The following questions refer to enrolling in a "diploma or certificate program with significant mathematics content" to improve your knowledge of mathematics.

62. To what extent did completing a diploma or certificate with significant mathematics content help you strengthen your knowledge of mathematics?

<table>
<thead>
<tr>
<th>To a great extent</th>
<th>Some extent</th>
<th>Very little</th>
<th>Not at all</th>
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</table>

63. To what extent do you feel completing a diploma or certificate with significant mathematics content helped you to be a better secondary mathematics teacher?

<table>
<thead>
<tr>
<th>To a great extent</th>
<th>Some extent</th>
<th>Very little</th>
<th>Not at all</th>
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</table>
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Section 5: Formal Professional Learning Activities #4

In this section, the questions will ask you about any formal professional learning activities you may have participated in to improve your knowledge of mathematics as a practicing secondary mathematics teacher in BC schools.

64. While you were teaching, did you learn mathematics content knowledge by completing university or college level mathematics courses that did not lead to a degree or certificate?

- Yes
- No
- Skip this question
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

One or More University or College Courses in Mathematics

The following questions refer to enrolling in "one or more university or college level courses in mathematics" to improve your knowledge of mathematics.

65. To what extent did completing university or college level mathematics courses help you strengthen your knowledge of mathematics?

<table>
<thead>
<tr>
<th>To a great extent</th>
<th>Some extent</th>
<th>Very little</th>
<th>Not at all</th>
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</table>

66. To what extent do you feel completing university or college level mathematics courses helped you to be a better secondary mathematics teacher?

<table>
<thead>
<tr>
<th>To a great extent</th>
<th>Some extent</th>
<th>Very little</th>
<th>Not at all</th>
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</table>
Section 5: Other Formal Professional Learning Activities

In this section you have considered the following formal professional learning activities to improve your knowledge in mathematics:
- masters or doctoral program
- undergraduate program
- diploma or certificate program
- university or college mathematics courses

67. While you were teaching, did you participate in any other formal professional learning activities, not mentioned above, to gain your mathematics content knowledge?

☐ Yes
☐ No
☐ Skip this question
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Formal Professional Learning Activities - Other

In this section you have considered the following formal professional learning activities to improve your knowledge in mathematics:
- masters or doctoral program
- undergraduate program
- diploma or certificate program
- university or college mathematics courses

68. What other types of formal professional learning activities did you participate in, not yet mentioned, to improve your mathematics content knowledge? Briefly describe each formal learning activity and list below.

Formal Activity 1: 
Formal Activity 2: 
Formal Activity 3: 
Formal Activity 4: 
Formal Activity 5: 

194
The following questions will ask you of any other professional learning activities, not previously mentioned, that you have participated in to improve your knowledge of mathematics as a practicing secondary mathematics teacher in BC schools.

69. Did you participate in any other professional learning activities, not previously mentioned, to improve your mathematics content knowledge?

- Yes
- No
- Skip this question
The following questions will ask you of any other professional learning activities, not previously mentioned, that you have participated in to improve your knowledge of mathematics as a practicing secondary mathematics teacher in BC schools.

70. What other types of professional learning, not previously mentioned, did you participate in to improve your mathematics content knowledge? Briefly describe each learning activity and list below.

Learning Activity 1: 
Learning Activity 2: 
Learning Activity 3: 
Learning Activity 4: 
Learning Activity 5: 
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Section 7: Preferred Professional Learning Activity

The following questions will ask you to rank the top 3 professional learning activities that were of most value to you.

71. Rank the TOP 3 professional learning activities you have participated in that was the most valuable to you in gaining your mathematics content knowledge. The list is reflective of the professional learning activities mentioned earlier.

<table>
<thead>
<tr>
<th>Learning from mathematics textbooks</th>
<th>Most Valuable</th>
<th>Second Most Valuable</th>
<th>Third Most Valuable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning from books about mathematics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning from teaching secondary mathematics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning from online resources</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>School or district supported learning communities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mentor or colleague</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mathematics study or reading groups</td>
<td></td>
<td></td>
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<tr>
<td>Social media or listserves</td>
<td></td>
<td></td>
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<tr>
<td>Provincial or national conferences</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School or district professional development days</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Administration initiated inservice workshops</td>
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<td></td>
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<tr>
<td></td>
<td>Most Valuable</td>
<td>Second Most Valuable</td>
<td>Third Most Valuable</td>
</tr>
<tr>
<td>--------------------------------------</td>
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<td>---------------------</td>
</tr>
<tr>
<td>Continuing studies, non-credit workshops</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>A master or doctorate degree in mathematics or one with significant mathematics content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>An undergraduate degree in mathematics or one with significant mathematics content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A diploma or certificate with significant mathematics content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Completed one or more university or college courses in mathematics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other - If selected as TOP 3, then please specify below</td>
<td></td>
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</tbody>
</table>

**72.** Any final comments regarding your professional learning experience in gaining your mathematics content knowledge.
The Professional Learning Experiences of Non-Mathematics Subject Specialist Teachers: A Descriptive Study

Section 8: Background Information

In this section, share some information about yourself and your professional practice.

73. What is your age?
   - 20-24 years old
   - 25-29 years old
   - 30-34 years old
   - 35-39 years old
   - 40-44 years old
   - 45-49 years old
   - 50-54 years old
   - 55-59 years old
   - 60-64 years old
   - 65+ years old

74. What is your gender?
   - Male
   - Female
75. How many years of teaching secondary mathematics in BC schools do you have?

- 0-4 years
- 5-9 years
- 10-14 years
- 15-19 years
- 20-24 years
- 25-29 years
- 30 or more years

76. Where have you taught secondary mathematics in BC schools? Check all that apply.

- Public schools
- Independent schools
- First nations schools
- Private schools
- Other (please specify)

77. How much of your teaching assignment is assigned to teaching secondary mathematics?

- Most
- More than half
- Some
- Very little

78. Do you consider yourself to be a secondary mathematics subject specialist teacher?

- Yes
- No

79. Rate your level of expertise as a secondary mathematics teacher.

- Expert
- Proficient Performer
- Competent Performer
- Advanced Beginner
- Novice

80. Rate your level of perceived subject matter content knowledge in mathematics.

- Expert
- Proficient Performer
- Competent Performer
- Advanced Beginner
- Novice