Mathematics Professors' Views on Written and Oral Assessment in Mathematics

by

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Abstract

One of the most striking differences between the Canadian educational system and the European educational systems is the importance given to oral assessment, particularly in mathematics courses. This thesis studies the views on oral assessment in post-secondary education from mathematics professors' perspectives. Seven mathematics professors and instructors are interviewed, being asked to explain how they perceive the oral examination, and how they compare the oral exam to the written exam. Four out of seven mathematics professors and instructors were educated in Poland, Romania, Bosnia, and Ukraine, and they are currently teaching mathematics at a university in Canada. The other three professors were educated in Canada, Germany, and the United States, and they are currently teaching at a university in Germany. Five participants had previously experienced oral examination in mathematics while the other two had never been exposed to oral examination in mathematics throughout their schooling.

The results show that similar beliefs about mathematics result in different beliefs about mathematics assessment. They suggest that the mathematics professors' views on oral assessment in mathematics are influenced by their schooling and teaching experiences with mathematics assessment, as well as the socio-cultural and the institutionalized mathematics assessment norms that exist within the teaching institution.

Keywords: oral assessment; oral examination; mathematics; beliefs; culture

For my family

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Chapter 1

Introduction

During all my schooling experiences in Serbia, from elementary to undergraduate levels, the interrogatory type of oral examination had been an important part of assessment practice in all subjects. At the university level, typically, students would have to take written exam first, and then after passing the written exam, they would go to the next stage, which would be taking an oral exam. During the oral exam, students would have access to a blackboard, paper, and pen. The exam would be conducted by the course instructor, and each oral exam session could last anywhere from 30 minutes to 1 hour, but sometimes even longer. Occasionally, during the oral exam, three or four students would be invited at the same time. The instructor would have prepared in advance a set of cards with questions of approximately equal difficulty, so a student would step in, randomly draw a card from the set of cards, and then, he/she would take a scrap paper and go back to his/her desk and start working on the chosen question. After some time working on the question, each student, one by one, would go up to the board and present his/her answer to the instructor. In addition, the teaching assistant would be in the same room, monitoring students and taking the protocol. During the oral exams, usually students would be able to receive some help if needed and would receive a grade immediately following the exam. A typical card would have one theoretical question (for example 'prove the fundamental theorem of calculus') and one exercise (for example 'calculate integral': $\int \arcsin^2 x \, dx$). On the other hand, the written examination would usually contain a larger number of questions, between five and ten, with a higher percentage of problem-solving tasks than an oral exam. It would be conducted in a classroom or an auditorium, lasting anywhere between three to five hours.

Moreover, this oral assessment practice was an essential part of my educational experience, and it still on-going in many other countries, but not in Canada. When I moved to Canada to pursue my PhD studies, and after having numerous discussions with some mathematics professors in Canada, I realized that oral examination in mathematics courses at university level is not present at all, even though there are a number of research studies that indicate that oral assessment has a positive impact on students' learning of mathematics (Boedigheimer et al., 2015; Iannone and Simpson, 2012, 2015; Lianghuo and Mei, 2007; Nelson, 2010; Nor and Shahrill, 2014; Odafe, 2006).

In the first three years of my PhD studies, I had the opportunity to work as teaching assistant in the department of mathematics for various undergraduate mathematics courses at Simon Fraser University. As a mathematics teaching assistant, my job duty consisted of providing mathematics tutorial sessions and grading students' homework assignments, quizzes, and exams. During this time, I was able to learn and understand that all undergraduate mathematics courses are assessed using multiple forms of written assessment only, such as: weekly homework assignments, quizzes, two mid-term exams, and a final exam.

Also, for the past two years, I have worked as a part-time lecturer in the mathematics department, and I have taught a 'Foundations of Analytical and Quantitative Reasoning' mathematics course to Indigenous students as a part of Interim Aboriginal University Preparation Program at Simon Fraser University. This program was created to help Indigenous students in transition to undergraduate studies at Simon Fraser University. As the teaching curricula and assessment practices are already prescribed to all undergraduate mathematics courses, for this course that I have taught, I have also used the same written assessment formats that have been implemented in all other undergraduate mathematics courses. Even though there was a time when I felt that an oral form of assessment would be more suitable for some students whom I have taught in my course, I did not have much option but to follow the pre-existing mathematics department assessment policy.

Initially, when I started my PhD studies at Simon Fraser University, I was not completely sure what would be the topic of my PhD dissertation, but I knew that I would be interested in researching the topic of assessment in mathematics classroom. It was at the end of my

first year of PhD studies when my senior supervisor, Prof. Peter Liljedahl, lent me a book "How to Grade for Learning, K-12" by O'Connor (2009). After I read the book, I started asking myself a question: "Where does oral assessment fit into the grading of mathematics?" I shared this question to Prof. Peter Liljedahl, and his immediate response was: "Why don't you start looking into the literature on oral assessment in mathematics and non-mathematics classrooms and see what you can find." And this is how my research journey began. I wanted to explore the views on oral assessment in mathematics at university level. In particular, my PhD dissertation evolved around looking into the mathematics professors' beliefs on mathematics assessment and mathematics assessment practice, with a specific focus on oral assessment in mathematics.

This PhD dissertation is composed of six chapters. The next chapter, Chapter 2, provides the literature review on the use of oral assessment in mathematics and non-mathematics classrooms. Also, it addresses the purposes of classroom assessment, types of oral assessment and its dimensions, the shift from oral to written assessment, the positive and negative aspects of oral assessment, and their use in the mathematics classroom. Chapter 3 presents the research on teachers' beliefs on mathematics, mathematics learning, teaching, and practices. Furthermore, it addresses the relationship between mathematics teachers' beliefs and their teaching practices, and it describes the relationships between teachers' views of mathematics and their impact on practice. It also introduces the research questions of this thesis. Chapter 4 provides the methodology of the study. It describes the participants, the process of their recruitment, and the data collection and analysis. Chapter 5 presents the findings and their discussion. Finally, Chapter 6 offers the summary of the research findings, the contributions that this thesis makes to the area of mathematics assessment, the limitations of this study, the recommendations for possible future research, and some final words.

Chapter 2

Assessment

This chapter addresses the literature that is related to the use of oral assessment in mathematics and non-mathematics classrooms. It begins with presenting the research on the purpose of classroom assessment, as well as a brief description of types of oral assessment, its dimensions, and the shift from oral to written assessment. Next, it presents the disadvantages and the advantages of oral assessment, along with the research that describes the use of oral assessment in mathematics. The last part of the chapter provides an overview of the literature on the positive aspects of oral assessment.

2.1 The Purpose of Assessment

According to Brown (2008), all teachers' beliefs about the purposes of assessment fall into one of these four categories: assessment as improvement of teaching and learning (improvement), assessment as making schools and teachers accountable for their effectiveness (school accountability), assessment as making students accountable for their learning (student accountability), and assessment as irrelevant to the life and work of teachers and students (irrelevant). In assessment as improvement of teaching and learning, the purpose for assessing students' knowledge or understanding is to gather information that would lead to changes in teaching and learning practices, so that improvement in student's achievement can be facilitated. When it comes to assessment as making schools and teachers accountable for their effectiveness, it focuses on demonstrating the quality of teaching and learning. For some, accountability has come to mean the responsibility of a school to produce high achievement test scores (Smith and Fey, 2000). Student accountability assessment has a

goal to hold students individually accountable for their learning, grades, and whether they have met various curriculum objectives. Contrary to the first three categories of assessment, in the fourth category, there are a number of reasons for teachers to consider an assessment irrelevant to student growth and achievement. Moreover, assessment may even unfairly impact certain students, create negative attitudes to testing, or be so inaccurate that it is unreliable. All of these such possibilities contribute to the notion that assessment could be irrelevant.

Also, many researchers believe that the primary purpose of classroom assessment should be to inform and promote students' learning (Black et al., 2004; Liljedahl, 2010; O'Connor, 2009), and that the main purpose of grades is recognized as communication, not competition (O'Connor, 2009). Assessment that promotes students' learning should provide information that teachers and students can use as feedback to help in modifying teaching and learning in order to meet learning goals and students' needs.

Reporting a student's learning progress signifies the growth that students are making in their learning. It should not be used as a means to rank or certify their competence. Therefore, communication has an important role and value in classroom assessment. This assessment as communication uses grading in a way to inform the learner about where he/she stands compared to learning goals. There is the assumption that assessment should be designed with the main intention to assign grades, but just a simple collection of grades does not provide sufficient information about student's learning and progress.

Furthermore, as educators, we value students' achievement of learning goals, and if we value something, then we should find a way to evaluate it. What we choose to evaluate, we show to students what it is we value, so by placing value on something we show our students that it is important (Liljedahl, 2010).

Also, it is assumed that teachers should value equal assessment for all students. But, if we, as we do, acknowledge that each student learns differently, then having a common approach to assessment would be inadequate. Hence, educators accept the need for differentiated instruction, so in order to deal with the individuality and variability of students,

they also need to accept the need for differentiated assessment to represent the learning of the fractured student collective (Liljedahl, 2010).

In terms of its purpose, assessment is often described having a summative or formative character (O'Connor, 2009). According to O'Connor, formative assessment (or assessment for learning) is designed to provide direction for improvement and/or adjustment to a program for individual students or for a whole class (i.e., quizzes, homework, and questions during instruction). On the other hand, summative assessment (or assessment of learning) is designed to provide information to be used in making judgments about a student's achievement at the end of a period of instruction (i.e., tests, exams, final papers, and projects). Several researchers stress that these two should not be seen as opposites, but rather as parts of a continuum (Brown Jr, 1999; Roos and Hamilton, 2005).

O'Connor (2009) also believes that educators should use a variety of assessment methods to incorporate eight intelligences: musical-rhythmic, visual-spatial, verbal-linguistic, logical-mathematical, bodily-kinesthetic, interpersonal, intrapersonal, and naturalistic. Understanding multiple intelligences means that teachers need to use different instructional and assessment activities. One way to address learner's differences is by having students develop portfolios as a collection of their work. Teaching through each of the intelligences promotes student strengths and greater opportunities for students to succeed. Therefore, according to O'Connor, the changes that we need are not changes in teachers' knowledge, but in the habits and rituals of teachers' practices.

2.2 Types of Oral Assessment and its Dimensions

There are two main types of assessment - oral and written. Joughin (1998) defines oral assessment as "assessment in which a student's response to the assessment task is verbal, in the sense of being 'expressed or conveyed by speech instead of writing' (*Oxford English Dictionary*)". In terms of different types of oral assessment, according to Joughin (2010), they can be categorized into three forms: presentation on a prepared topic (individual or in groups); interrogation (covering everything from short-form question-and-answer to a doctoral oral exam); and application (where candidates apply their knowledge live in a

simulated situation, e.g., having trainee doctors undertaking live diagnoses with an actor-patient).

Joughin (1998) identifies a comprehensive categorization system for oral assessment based on six different dimensions. These are:

- The dimension of *primary content type*, whether the aim of the assessment is to assess knowledge and understanding, applied problem solving ability, interpersonal competence or personal qualities.

- The dimension of *interaction*, whether the action is presentation, in which no questioning or discussion occurs, or highly interactive dialogue, or combined.

- The dimension of *authenticity*, whether the assessment is contextualized or decontextualized. Oral assessment is completely contextualized when it is conducted in contexts of professional practice. An example of it would be the medical examination of patients in hospital settings. Oppositely, oral assessment is considered to be decontextualized when the assessment focuses on academic learning. An example of it would be the oral defense of a doctoral thesis, conducted in a classroom or public auditorium or on video conferencing services like Zoom.

- The dimension of *structure*, whether the structure of the assessment is either closed and formal, with little interaction between student and assessor, or open, with less structure and the opportunity for dialogue between student and assessor. In this closed structure format, the list of fixed pre-set questions is applied to all students. On the other hand, the open structure approach consists of a loose flow of dialogue, questions and answers, where the assessor shapes the questions in accordance to the student's answers.

- The dimension of *examiners*, whether the oral assessment may include components of self-assessment, peer-assessment, or authority-based assessment (the most common). In other words, the examiner dimension concerns who judges the worth of the student's responses.

- The dimension of *orality*, whether the oral assessment is purely oral by word-of-mouth, or combined with other media such as a written paper or a physical work such as an architectural design.

This thesis focuses on *oral examination*, meaning assessment done at the end of an activity with a mainly summative purpose, that involves assessing knowledge and understanding with elements of both presentation and dialogue that comes from interrogation form of oral assessment, decontextualized, authority-based, having a relatively open structure, and combines oral medium with writing on a paper and board, but it is not the written answer itself that is primarily judged. The term *assessment* will be used to represent a broader range of evaluation activities, but also, as most assessments in undergraduate mathematics are exams, in this thesis, terms *assessment* and *exam* will be used interchangeably.

2.3 Shift from Oral to Written Assessment

The oral examination has a very long history in higher education. Prior to the beginning of the 20^{th} century, oral examination was a standard practice in the UK, which later on failed because of accusations of bias and the apparent efficiency of written exams. Stray (2001) studied oral examination testing at Cambridge and Oxford in the 16^{th} century, when examinations were conducted in Latin, orally, in public, with the participation of the academic community:

> Its verbal jousting, which might go on for two hours or more, constituted a public negotiation not just between examiner and examinee, but also between several participants, since students were disputing with one another and with any graduates who might choose to intervene. (p. 34)

According to Stray, four factors are identified as being crucial in causing the shift by switching from oral to written examination: the move from group socio-moral to individual cognitive assessment in the later 18^{th} century; the differential difficulty of oral testing in different subjects; the impact of increased student numbers; the internal politics of Oxford and Cambridge.

Despite this shift, the transition from using oral to written only has not happened everywhere. There are still many countries that maintain an oral assessment in most academic subjects as an important part of their assessment practice (Brown and Knight, 1994; De Vita and Case, 2003; Forrest, 1985; Hubbard, 1971). Some of these countries are Hungary, Italy, Germany, and the Czech Republic.

Looking at the history of written examination, Stray (2001) notes that the written examination became the norm in the UK starting at the beginning of the 20^{th} century. Since then, the primary method of assessment in the mathematics classroom became strictly based on closed book written examinations. The USA, in particular, appears to be dominated by closed book written examinations (Gold, 1999; Nelson, 2010). Also, the majority of mathematics students in the UK are to be assessed predominately using high stakes, closed book examinations at the end of almost every module (Iannone and Simpson, 2011). Written assessment, most commonly in the form of examinations, can also take the form of quizzes, projects, assignments, papers, essays, journals, dissertations, and portfolios.

2.4 Disadvantages and Advantages of Oral Assessment

The main topic that has been discussed in oral assessment literature is related to disadvantages and advantages of oral in comparison to written assessment, specifically focusing on understanding assessment from the learner's and the teacher's perspectives.

In terms of disadvantages of oral assessment in comparison to written ones, two things came up: fairness and anxiety (Henderson et al., 2002; Hounsell et al., 2007; Huxham et al., 2012; Joughin, 2007). Romagnano (2001) believes that all assessments of students' mathematical understanding are subjective, and that objectivity does not exist. Also, he thinks that a conclusion about a student's knowledge would require the teacher's judgment, and, therefore, "No "objective" assessment occurs; subjective—that is, human—knowledge, beliefs, judgments, and decisions are unavoidable parts of any assessment scheme" (p. 36). Human judgment about mental constructs is introduced when test designers decide, "what items to include on the test, the wording and content of the items, the determination of

the 'correct' answer, ... how the test is administered, and the uses of the results" (FairTest: The National Center for Fair and Open Testing, 2012).

When it comes to oral assessment and anxiety, there is a perception that oral assessment may make students more anxious than other forms of assessment for two reasons: oral assessment anxiety may be primarily related to its unfamiliarity and oral assessment anxiety is associated with the conception that an oral task requires deeper understanding and the need to explain to others. Henderson et al. (2002) studied oral assessment in social work education, and they found that before taking oral assessments, students were anxious about them, but after experiencing them, students had more positive views about them. Furthermore, by the time the students had entered professional practice, they were able to recognize the importance of oral assessment in terms of its authenticity and value for later employment. Similarly, Huxham et al. (2012) point out how undergraduate biology students were able to balance the issue of anxiety with usefulness and authenticity of oral assessment. When it comes to students' anxiety and oral assessment, Hounsell et al. (2007) note that, "It is not clear whether oral assessments are scarier or just more novel" (p. 34). Also, Huxham et al. (2012) note that oral assessment anxiety may be primarily related to its unfamiliarity. In his phenomenographic study of student experiences with oral presentations, Joughin (2007) notes that greater anxiety about oral compared to written assessment is associated with a richer conception of the oral task as requiring deeper understanding and the need to explain to others. Despite of all of these disadvantages, at the same time, however, oral assessment is not without its advantages.

Huxham et al. (2012) discuss five main advantages of oral assessment: they develop oral communication skills, they are authentic (as they more accurately mimic job interviews or the way people defend ideas in verbal exchanges), they can be seen to be more inclusive, they can be a powerful way of evaluating understanding, and they are more difficult to cheat in. Based on their study, they found that many undergraduate biology students performed better in oral compared with written tests. When these students were asked about their attitudes to the two different assessment approaches, many students thought that oral

assessment was more useful than written assessment. The following comments exemplified the students' views on oral assessment:

> I thought it was easier to explain yourself and explain what you are doing to a person rather than trying to [write it down]. It is easy to get muddled up with your words and try to explain something in writing. If you talk to someone in person it's a lot more natural. (p.132)

> I think I performed to a higher standard than in written tests. The reason for this I have dyslexia, and dyspraxia, so reading and writing for me has always been harder than just plain speech. (p.133)

Similarly, Joughin (2007) points out that many students believe that oral presentations are more demanding than the written assignments, more personal, require deeper understanding, and lead to better learning. One of the advantages of oral assessment, noted by Joughin (1998), is that the interaction allows for probing knowledge through dialogue that is genuinely individual, which, "Gives assessment an inherent unpredictability in which neither party knows in advance exactly what questions will be asked or what responses will be made" (p. 371). Therefore, oral assessment might be considered fairer than some other forms of assessment. It makes plagiarizing very difficult, in which students must explain their own understanding using their own words and, unlike other examinations, oral assessment with a tutor prevents one small gap in knowledge completely stalling a solution (Joughin, 1998). Also, Joughin notes that oral examinations are more authentic than most types of assessment. He describes this authenticity as, "The extent to which assessment replicates the context of professional practice or real life" (p. 371). Moreover, Roecker (2007) found that oral examinations allow the opportunity for performance-related feedback, provided during the examination, and the resulting boost to student knowledge and motivation.

The literature on oral assessment in higher education is mostly dominated by the lecturer's or tutor's perspective and not much of the learner's perspective (Joughin, 1998). When it comes to pre-service teachers' and professors' insights on implementation of an oral assessment, Badger (2010) found that oral assessment can determine students' critical

thinking abilities, which otherwise would not be possible to the same degree in traditional written assessment. Furthermore, his research showed that professors viewed oral assessment as an effective way to assess students' communication skills, ethical reasoning abilities, and probe deeper levels of students' understanding and critical thinking abilities by asking questions that would identify gaps in students' knowledge.

Although oral assessment is used in many areas, there is very little literature examining the use of oral assessment. In the UK comprehensive review of the literature on innovative assessment, it shows that less than 2% of the papers address oral assessment. Of 317 papers considered, only 31 dealt with 'non-written assessment', which includes: oral examination, group and individual oral presentation (oral group presentations were by far the most commonly cited non-written assessment, at 50% of the total sample), debate, artefact (such as a display stand or non-written poster), audio or video recording, and role-play. Within this category of non-written assessment, only 4 papers addressed the use of oral examinations (Hounsell et al., 2007). All of these non-written assessments addressed undergraduate assessment, with the exception of a single article considering the use of oral exams for PhD students. Also, most of the research on oral assessment focuses mainly on liberal arts subjects, indicating almost complete absence of research that studies oral assessment in mathematics classrooms.

2.5 Oral Assessment in Mathematics

Nor and Shahrill (2014) introduced a study on the integration of posters and oral presentations into teaching and learning of trigonometry. Of 28 first-year secondary school students, 15 girls divided themselves into 3 groups of 5, while the 13 boys divided themselves into 2 groups of 6 and 7 respectively. These students were given the flexibility of forming their own group, which had led to single sex groupings. Students were given a pre-test prior to the 'project' (poster and oral presentations) and a post-test afterwards, and the questions on the pre-test and post-test were identical. The results obtained from this study showed a significant improvement in students' learning and provided evidence for the positive impact of using posters and oral presentations on students' understanding and mathematical

knowledge. The mean of the pre-test of the whole class were found to have improved from 29.80 to 67.05 in the post-test, which is an increase by 37.25, showing a significant improvement. In addition, when it came to students' perceptions and attitudes towards the use of posters and oral presentations in the mathematics classroom, a majority of the students enjoyed working on the mathematics posters and oral presentations, and they believed that doing mathematics posters and oral presentations helped them to learn mathematics. The students were provided with a survey regarding their perceptions and attitudes towards the use of these kinds of projects in the mathematics classroom. Furthermore, 65.4% of the students enjoyed working on the mathematics poster and oral presentations, followed by 88.5% of the students who believed that doing mathematics poster and oral presentations helped them to learn mathematics. In addition, when students were introduced to this project, most of them were very unfamiliar with it, so it caused them to feel anxious about it. Moreover, one of the students thought that presenting mathematics meant they had to search for the history of the topic and present it. At the end, by having students creating the posters and presenting them orally, it increased students' involvement in class and made them accountable for their learning. These tasks also eliminated the previous problems such as having students choosing not to hand in their homework or simply copying the answers from their classmates.

Similarly, Nelson (2010) conducted a study on an innovative approach to teaching Calculus I, which was initiated in a two-semester course designed for students at risk of failing Calculus I. The treatment consisted of voluntary oral assessment offered before every written examination. The treatment class for this study had 36 students, and 62% of these students were considered at risk of failing Calculus because their placement scores were less than 18/30. On the other hand, the control group consisted of all students in regular one-semester lecture classes in Fall 2003. These classes ranged from 96–140 students, and only 16% of the control group was "at risk." The results showed that the treatment students did significantly better than the control group on course grades, as well as on a common final exam that tested both concepts and procedures. Moreover, the treatment students, who were considered at-risk, completed Calculus I, they were retained at the university,

and enrolled in and passed Calculus II at dramatically higher rates than at-risk students in the control group. After the first test, Nelson asked participants to answer several short survey questions in order to determine if they thought that oral assessment was beneficial. As a result of this, many students discussed how oral assessment helped them assess their own knowledge. One student commented that the oral assessment "Let me test my knowledge, and allowed me to recognize my gaps of understanding in some areas" (p. 51). Some students discussed the effect of oral assessment on improving their understanding, "We went over problems in depth: it helped work out any things we didn't understand" (p. 51).

In another research study, done by Lianghuo and Mei (2007), they introduced an exploratory study on the integration of oral presentation tasks into mathematics teaching and learning in five classes taught by different teachers in two Singapore secondary schools over a substantial period of time. A total of 16 questionnaire items were constructed to measure three aspects of students' general attitudes toward the use of oral presentation tasks: perceptions about their own ability to perform, beliefs in the usefulness, and acceptance of oral presentation tasks. In the high-performing school, the results showed that although students did not generally have positive acceptance towards the use of oral presentation, students had positive beliefs about the usefulness of doing oral presentation. For instance, based on a questionnaire that was administered, 45% of the students believed that '*doing mathematics oral presentation helps me to be more aware of my understanding of mathematics*' (vs. 32.5% who disagreed), 42.5% of the students believed that '*doing mathematics oral presentation makes me think broader and deeper about mathematics*' (vs. 35% who disagreed), and more than 70% of the students also had the same opinion that '*listening to other classmates' oral presentation is helpful for me in learning mathematics*'. Similarly, in the non-high performing school, the results showed that the students also did not show very positive responses to items corresponding to their acceptance towards the use of oral presentation. However, the data did reveal that most students generally believed in the usefulness of oral presentation. For instance, more than 60% of the students '*agreed*' that '*listening to other classmates' oral presentation is helpful for me in learning mathematics*'.

Overall, Lianghuo and Mei believe that these positive views were related to the nature and pedagogical values of oral presentation activities.

Moreover, "[o]ral exams increase your confidence because you never want to look stupid one-on-one with your instructor, so you try very hard to understand" (Boedigheimer et al., 2015, p. 110). This comment was made by one of the students from this study. They found that the oral exam gives the instructor considerable insight into students' understanding, allows students to "take charge" in their explanations, and provides immediate feedback. Furthermore, they concluded that oral exams appear to encourage students to engage deeply with the course material, to learn to express technical material clearly and concisely, and to gain ownership of the material. Also, the presentation abilities and confidence that students develop through oral exams help prepare them for their professional careers. For this reason, in 2003, it was decided to incorporate individual oral exams into some of mathematics and operations research courses at the United States Air Force Academy (USAFA). As reported in 2015, since 2003, faculty members in their department have given oral exams in 11 courses, administered by more than 25 instructors to over 1000 cadets.

An example of using oral exams successfully at the undergraduate level can also be found in Odafe's (2006) study, in which, through the use of effective co-operative learning and oral examination, students learned to engage actively in mathematical reasoning in a social setting. Moreover, students who were doing badly in traditional examinations did better on the oral examinations. Of 21 college algebra students, 19 admitted putting in more time and effort into preparing for the oral examination than they did into preparing for the traditional pen-and-paper examination. The other 2 students claimed to have spent just about the same amount of time and effort on both forms of assessment. Furthermore, after conducting an oral examination, students were provided with a survey, and the survey results indicated that some 14 students preferred the oral to the written examinations. These students claimed that they studied and learned more in the process, and that this type of assessment technique enabled them to identify their mistakes and misconceptions and got them corrected immediately, by being provided with immediate verbal feedback during the examination. Only 2 students favored both forms of examination equally, and the remaining

5 students preferred the written examinations. On the other hand, some students reported being nervous, anxious, and even sad when they got a problem wrong, where the sadness came from feeling that they had let their group members down; the time involved in the process was too long; and some students admitted not being able to explain things to others and, as such, found this method to be harder than simply writing down one's responses on paper. Additionally, by observing the students as they were presenting their solutions, Odafe concluded that the probing questions revealed students' misconceptions and areas of difficulty, and he was able to confirm that a few students memorized the solutions to some problems when the solutions (as provided by others) did not make sense to them. Therefore, if properly implemented, oral assessment can be a viable assessment method for assessing students' learning in higher education (Iannone and Simpson, 2015).

Iannone and Simpson (2015) conducted the study at undergraduate level that had the aims to uncover and describe the views of mathematics students who took part in a small trial of 'oral performance assessment,' which involved assessing knowledge and understanding with elements of both presentation and dialogue. This oral performance assessment had a relatively open structure and combined oral medium with writing on a board. The results of this study suggested that, despite concerns about anxiety and fairness, students saw oral assessment as encouraging a focus on understanding, being relatively authentic and reactive to their needs. When it comes to students' anxiety, one of the most common comments was about the lack of familiarity:

> I think that you know what to expect from an exam paper [...] You don't know [...] cause obviously you don't know who is gonna be your tutor. You don't know how it's gonna start [...] I mean to be fair it was pretty much exactly what we were told it was going to be. You prepared your questions. You pick one and get made to do another one. So it wasn't any nasty surprises. But there is a bit of a weird concept. (p. 976)

The most common comments, when it comes to the issue of fairness, focused on the number of different assessors, the contingent questions and the comparability between the assessment as experienced by different students.

> Because there was like two or three tutors who were doing the tutorials and they were [...] I think they were run like quite differently. For some people said that they were asked for some like [...] extension questions whereas I just answered the question out of the ones I prepared. (p. 978)

When it came to understanding, all of the students referred to the impact of the assessment on understanding in terms of the understanding they developed in preparing for the tutorial, its development through the interaction in the tutorial or the way in which that understanding was assessed. One of the most common comments was:

> I prepared a lot more for the oral one obviously cause I needed that I have to [...] generally understand what I was talking about so I can actually communicate it whereas I think that sometimes like on paper you just kind of [...] write the answer and not necessarily completely understand the whole theory behind it. So, I think I definitely had to do more work to do this. (p. 979)

The important characteristic that was pointed out by most of the students, when it came to reactiveness, was that the assessor could respond to the performance of the student and to their needs, and this brought up the opportunity for the assessor to help the student over a gap in knowledge:

> In an exam, if you don't know a question, you can get stuck and you can't go any further with the question but if you get a little bit of guidance maybe you can show that you can work through a bit more. You've got a second chance. (p. 982)

At last, when it comes to authenticity, many students believed that by communicating their solutions and responding to questions, it could help them gain skills required in the job market.

> I think it is very important because when you go out in the wider world you are not going to be [...] you are not going to get somebody saying to you – oh do this problem and hand it to me next week. Somebody is going to say to you: oh

> can you sort this out and can you explain to me how to do it. And I think it is a much more useful skill to be able to explain your thinking to somebody else than to be able to write the answer and hand it in – I think it is a much more useful skill. (p. 982)

Similarly, Iannone and Simpson (2012) discussed students' experiences about oral assessment as an alternative to weekly coursework sheets and to final examinations. The week after the oral assessment, at the beginning of a lecture, 85 students were asked to complete a questionnaire about their experience of the one-to-one tutorials. The experience was generally positive, leading many students to suggest it as a possible alternative or addition to the existing forms of assessment. Thus, when it comes to the comparison between the oral assessment and weekly homework, most of the students thought that oral assessment had more positive aspects than the weekly sheets. Some of the positive aspects were that oral assessment made students think more about the material, encouraged them to understand the material better, challenged them, made them remember the material longer after the assessment, and did not allow them to get high marks without understanding. Moreover, the reasons why students felt that way were because they thought that coursework sheets lacked immediate feedback, and with weekly sheets it was easy to gain marks with answers which were not really understood, and then forget about the material once the coursework was returned. On the other hand, when it came to comparison between oral assessment and the final examination, students thought that oral assessment made them to think more about the material, made them to learn more while preparing for it, and encouraged them to learn more beyond the course material. Additionally, students were also asked to fill in an open response box by commenting their experiences of the one-to-one tutorials and anything that they would like to say about how they would like to be assessed in mathematics courses. Of 85, 73 students commented, and most of them were being positive about oral assessment as an alternative to weekly coursework sheets, but negative about them as an alternative to examinations. One student commented:

> I think it would be better to have a combination of both, similar to the [. . .] weighting of tutorials to final examinations. The risk with purely final exams is that one bad day can affect your mark quite significantly. (p.188)

Therefore, students saw the oral assessment as the potential value for gauging and promoting understanding of the material, while not replacing the final, high-stakes, written, closed-book exam, seeing it as the 'gold standard' of assessment. Even though many students and professors prefer to use only written, closed-book assessment, there are some aspects of knowing mathematics that are difficult to assess in a written test.

For instance, Fyhn (2015) conducted a study on how a local oral examination in Norway considers motivation, attitudes, beliefs and creativity, which are the aspects of knowing mathematics that are difficult to assess in a written exam. Moreover, in her study, it turned out to be that there were some teaching aims that a written test could not assess: to develop, use, and elaborate on methods for mental calculations and the use of sketches and free drawing in geometry. In Norway, students have to take two different examinations in mathematics at the end of the compulsory school: A national written mathematics examination and a local oral mathematics examination (local oral assessment in Norway was introduced with the intention to test for what is difficult to show in a written test). Furthermore, the oral examination in Norway started in 1990-1992, and it has developed into the 2014 examination form, aiming at the form of a mathematical conversation. In 1992, students had the opportunity to give a short presentation of their previous project work or similar, and then discuss this with their teacher who asked questions. Considering the fact that students' project work was to be used for the examination, it would mean that the students' interests, motivation and beliefs would be valued. On the other hand, in 2014, students would have one day at school to prepare a presentation of a problem given by the teacher, and at the examination, students would discuss their presentation with the teacher and the external sensor.

In summary, in terms of advantages of oral assessment over written ones, taken from the provided literature review, oral assessment in mathematics and in other subjects:

- provides immediate feedback and immediate grade (Boedigheimer et al., 2015; Iannone and Simpson, 2012; Odafe, 2006; Roecker, 2007);
- does not allow plagiarism (Huxham et al., 2012; Joughin, 1998; Nor and Shahrill, 2014);
- helps develop better oral communication skills (Badger, 2010; Huxham et al., 2012);
- promotes deep comprehension of the learned material (Iannone and Simpson, 2012, 2015; Joughin, 2007; Lianghuo and Mei, 2007; Nelson, 2010; Nor and Shahrill, 2014; Odafe, 2006; Roecker, 2007);
- encourages students to deeply/actively engage with the course material (Boedigheimer et al., 2015; Iannone and Simpson, 2012; Nor and Shahrill, 2014; Odafe, 2006);
- helps students gain ownership of the learned material (Boedigheimer et al., 2015);
- is more personal/provides individualized contact between teacher and student (Joughin, 2007);
- helps students learn to express technical material clearly and concisely (Boedigheimer et al., 2015);
- allows for probing knowledge through dialogue (Badger, 2010; Joughin, 1998; Odafe, 2006);
- provides long-lasting mathematical knowledge (Iannone and Simpson, 2012);
- is authentic/helps prepare students for their professional careers (ex. career interviews) (Boedigheimer et al., 2015; Henderson et al., 2002; Huxham et al., 2012; Iannone and Simpson, 2015; Joughin, 1998);
- helps develop better presentation skills (Boedigheimer et al., 2015);
- helps students build the confidence (Boedigheimer et al., 2015);
- is reactive to students' needs (Iannone and Simpson, 2015);

- provides the opportunity for assessing students' mental math skills (ex. mental calculation) and the use of sketches and free drawing in geometry (Fyhn, 2015);
- provides the opportunity to better understand students' attitude, beliefs, motivation and creativity (Fyhn, 2015);
- encourages students to put more effort/time in preparing for it (Iannone and Simpson, 2012; Joughin, 2007; Odafe, 2006);
- prevents one small gap in knowledge completely stalling a solution (Joughin, 1998);
- can determine students' critical thinking abilities (Badger, 2010).

Chapter 3

Teachers' Beliefs and Teachers' Practice

A large amount of research on teachers' beliefs focuses on beliefs about mathematics, mathematics teaching and mathematics learning (Beswick, 2007; Cross, 2009; Ernest, 1989; Handal, 2003; Liljedahl, 2009; Maasz and Schlöglmann, 2009; Philipp, 2007; Raymond, 1997; Stipek et al., 2001; Thompson, 1992; Žalská, 2012). However, in the most recent review of assessment in Mathematics Education, there have been almost no research on students' and teachers' beliefs about assessment in mathematics (Suurtamm et al., 2016).

Although the goal of this thesis is to study mathematics beliefs and practices of participants who teach mathematics at university level, the vast majority of research addresses beliefs and practices of mathematics school teachers. Therefore, this chapter takes a brief look at the research on teachers' beliefs on mathematics, mathematics learning, teaching, and practices. It also discusses the relationship between mathematics teachers' beliefs and their teaching practices. It presents a diagram by Ernest (1989), which addresses the relationships between teachers' views of mathematics and their impact on practice. Finally, it introduces the research questions of this thesis.

3.1 Teachers' Beliefs on Mathematics, Mathematics Learning and Teaching, and Assessment

According to Skott (2015), beliefs are "results of substantial social experiences" (p. 19). Richardson (1996) describes three categories of experience that can influence beliefs about teaching: the personal experiences, experiences with schooling and instruction, and experi-

ences with formal knowledge. When it comes to personal experiences, this type of experience includes all aspects of life that may affect an individual's beliefs about teaching, such as socio-economic background, gender, geographic location, religious upbringing, understandings of the relationship of schooling to society, and other forms of personal and cultural understandings. In terms of experiences with schooling and instruction, these experiences are based on one's own previous experiences of teaching and learning in their classrooms. For example, when students enroll in preservice teacher education programs, they already come with built-in beliefs about the nature of teaching based on their own experiences as students. In case of experiences with formal knowledge, formal knowledge is considered an understanding that have been agreed upon within a community of scholars as worthwhile and valid.

Furthermore, Raymond (1997) describes different factors which can influence teachers' beliefs about mathematics: past school experiences, early family experiences, and teachers' education programs where they were trained. When it comes to past school experiences, these experiences are based on past successes in mathematics as a student. In terms of early family experiences, these are based on parents' views of mathematics and their educational background. And in case of teachers' education programs that provide teachers' training, these programs consist of mathematics content courses, methods courses, field experiences, and student teaching. Raymond also describes different factors that can influence the teachers' beliefs about mathematics teaching practices: social teaching norms, immediate classroom situations, and personality traits of the teacher. Social teaching norms consist of school philosophy, administrators, standardized tests, curriculum, textbooks, and resources. Immediate classroom situations consider students (abilities, attitudes, and behavior), time constraints, and the mathematics topic at hand. In terms of personality traits of the teacher, these include teacher's confidence, creativity, humor, and openness to change.

When it comes to different types of beliefs, Green (1971) introduced two types: *evidential* and *non-evidential*. Beliefs are held *non-evidentially* when they are held without regard of evidence, or opposite to evidence, or apart from good reasons. These non-evidential beliefs cannot be modified by introducing reasons or evidence and cannot be changed by rational

criticism. On the other hand, beliefs that are based on evidence or reasons are beliefs held *evidentially*. These evidential beliefs can be rationally criticized and modified in the light of further evidence or better reasons.

Green also introduced three dimensions of belief systems: *quasi-logical relationship*, *psychological strength*, and *isolated clusters*. In *quasi-logical relationship*, beliefs can be either *primary* or *derivative* (a belief that is derived from a primary belief). For instance, if a student believes that learning mathematics is useful for his/her life, this would be considered a primary belief. If a student thinks that it would be important to work hard in mathematics class and try to relate problem-solving exercises to everyday life, these would be considered the derivative beliefs. In *psychological strength* dimension, beliefs can be either *central* or *peripheral*. Central beliefs are held most strongly, where the peripheral beliefs are held less strongly and can be changed more easily. For instance, an experienced teacher holds more central, deep-rooted beliefs, where the new hired teacher holds more peripheral, changeable beliefs. In *isolated clusters* dimension, beliefs are held in clusters, where "nobody holds a belief in total independence of all other beliefs. Beliefs always occur in sets or groups" (p. 41). An example of this would be when we talk about mathematics, we could broadly classify beliefs about mathematics in relation to the nature of mathematics, teaching and learning of mathematics, the nature of mathematical knowledge and understanding, etc.

Beliefs about mathematics can be classified into three groups: *the traditional perspective, the formalist perspective*, and the *constructivist perspective* (Dionne, 1984). Törner and Grigutsch (1994) refer to these three groups as a toolbox, system, and process. In the *traditional perspective 'toolbox'*, mathematics is seen as a set of skills, which involves doing mathematical calculations and using rules, procedures, and formulas. In the *formalist perspective 'system'*, mathematics is seen as logic and rigor, whereby doing mathematics is considered writing rigorous proofs and exact definitions. In the *constructivist perspective 'process'*, mathematics is seen as a constructive process, which involves learning mathematics through the process of problem-solving, building rules and formulas in order for students to be able to experience the actual doing of mathematics and finding relations between different notions. In this constructive process, two types of understanding and knowledge of

mathematics could be considered. *Relational understanding* – as knowing both what to do and why, and *instrumental understanding* – as the ability to execute mathematical rules and procedures (Skemp, 1976). Similarly, *conceptual knowledge* – a knowledge rich in relationships, which can be thought of as a connected web of knowledge, a network in which the linking relationships are as prominent as the discrete pieces of information, and *procedural knowledge* – a knowledge that consists of rules or procedures for solving mathematical problems (Hiebert and Lefevre, 1986).

In terms of teachers' views of the nature of mathematics, as their belief systems on the nature of mathematics as a whole, they form the basis of the philosophy of mathematics, although some teachers' views may not have been elaborated into fully articulated philosophies. Therefore, "teachers' conceptions of the nature of mathematics by no means have to be consciously held views; rather they may be implicitly held philosophies" (Ernest, 1989, p. 249). Based on of their observed occurrence in the teaching of mathematics, Ernest describes three philosophies of mathematics: *instrumentalist*, *Platonist* and *problem-solving*.

- In the *instrumentalist* view of mathematics, mathematics is an accumulation of facts, rules and skills to be used in the pursuance of some external end. Thus, mathematics is a set of unrelated but utilitarian rules and facts.

- In the *Platonist* view of mathematics, mathematics is a static but unified body of certain knowledge. Mathematics is discovered, not created.

- In the *problem-solving* view of mathematics, mathematics is dynamic, continually expanding field of human creation and invention, a cultural product. Mathematics is a process of enquiry and coming to know, not a finished product, for its results remain open to revision.

According to Ernest, these three philosophies of mathematics, as systems of beliefs, can be assumed to form a hierarchy. In this hierarchy, instrumentalism is at the lowest level, involving knowledge of mathematical facts, rules and methods as separate entities. The Platonist view would be at the next level, involving a global understanding of mathematics as a consistent, connected and objective structure. At lasts, at the highest level, the problem-

solving view perceives mathematics as a dynamically organized structure located in a social and cultural context.

On the other hand, when it comes to the model/view of teaching mathematics, this model represents the teacher's conception of the type and range of teaching roles, actions and classroom activities associated with the teaching of mathematics. Ernest points out three different models that can be specified through the teacher's role and intended outcome of instruction:

TEACHER'S ROLE	INTENDED OUTCOME
Instructor	Skills mastery with correct performance
Explainer	Conceptual understanding with unified knowledge
Facilitator	Confident problem posing and solving

In addition, he suggests that the use of curricular materials in mathematics is also very important in a model of teaching and points out three patterns of use:

- The strict following of a text or scheme
- Modification of the textbook approach, enriched with additional problems and activities
- Teacher or school construction of the mathematics curriculum

Similarly, when it comes to the teacher's mental model of the learning of mathematics, this model represents the teacher's view of the process of learning mathematics, what behaviors and mental activities are involved on the part of the learner, and what constitute appropriate and prototypical learning activities. Lastly, Ernest points out two key constructs for these models:

- learning as active construction, as opposed to the passive reception of knowledge;
- the development of autonomy and child interests in mathematics, versus a view of the learner as submissive and compliant.

3.2 Teachers' Beliefs vs Teachers' Practice

Teachers' views "can provide significant insight into what teachers value and the relative importance they assign to different aspects of mathematics or the teaching of mathematics" (Willson and Cooney, 2002, p. 131). There are numerous papers written about the inconsistency between teachers' beliefs and teachers' practice. Most of this research showed that there is a difference between teachers' beliefs and their actual classroom practice (Vacc and Bright, 1999; Willson and Cooney, 2002). On the other hand, there is a large body of research that indicates the disjunction between teachers' intentions of practice and their actual practice (Cooney, 1985; Karaagac and Threlfall, 2004; Noyes, 2004; Skott, 2001).

Ernest (1989) suggests that the teaching practice of mathematics depends fundamentally on the teacher's system of beliefs, and in particular, on the teacher's conception/view of the nature of mathematics and mental models/views of teaching and learning mathematics. Besides, according to Ernest, the practice of teaching mathematics also depends on the social context of the teaching situation, particularly the constraints and opportunities that provides, and the teacher's level of thought processes and reflection. These factors determine the autonomy of the mathematics teachers within their teaching.

Research that have mathematics undergraduate students as participants (Ortiz-Robinson and Ellington, 2009; Stylianou and Blanton, 2002; Yackel et al., 2000; Yoon et al., 2011) have documented the importance of social and socio-mathematical norms that allow students to take a more active role in their learning of mathematics. Yackel and Cobb (1996) define social norms as general classroom norms that regulate the social interactions in the classroom, and they can be applied to any subject matter area while socio-mathematical norms refer to those normative understandings that are specifically related to the fact that the subject of study is mathematics. According to Yackel and Cobb, normative understandings of what is considered as mathematically different, mathematically sophisticated, mathematically efficient, and mathematically elegant in a classroom are socio-mathematical norms. Also, what is considered as an acceptable mathematical explanation and justification is a socio-mathematical norm. For better clarification of the distinction between social norms and socio-mathematical norms, Yackel and Cobb explain as follows:

> The understanding that students are expected to explain their solutions and their ways of thinking is a social norm, whereas the understanding of what counts as an acceptable mathematical explanation is a sociomathematical norm. Likewise, the understanding that when discussing a problem students should offer solutions different from those already contributed is a social norm, whereas the understanding of what constitutes mathematical difference is a sociomathematical norm. (p. 461)

As social norms are expressions of the normative expectancies in the classroom, social norms can be thought of as taken-as-shared beliefs that constitute a basis for communication and make possible the smooth flow of classroom interactions (Cobb et al., 1993). Within the classroom setting, social norms define both the teachers' and students' roles.

Ernest (1989) provides a diagram that describes the relationships between teachers' views of the nature of mathematics and their models of its teaching and learning (see Figure 3.1).

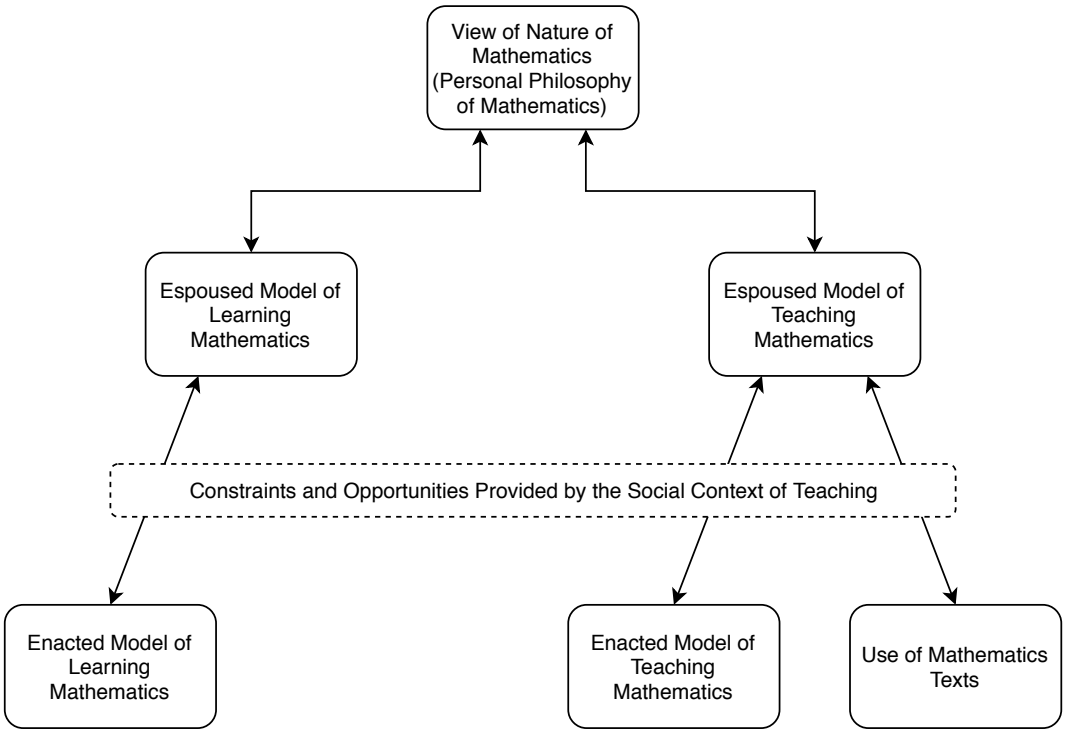

Figure 3.1: Relationships Between Beliefs, and Their Impact on Practice (Ernest, 1989)

This illustrative diagram shows how teachers' views of the nature of mathematics provide a basis for the teachers' mental models of the teaching and learning of mathematics, as indicated by the downward arrows. Hence, for example, the instrumental view of mathematics is likely to be associated with the instructor model of teaching, and with the strict following of a text or scheme. Also, it is likely to be associated with the child's compliant behavior and mastery of skills model of learning. On the other hand, mathematics as a Platonist unified body of knowledge is likely to be associated with the teacher as explainer and learning as the reception of knowledge model. And lastly, mathematics as problem solving is likely to be associated with the teacher as facilitator and learning as the active construction of understanding model, possibly even as autonomous problem posing and solving.

According to Ernest, these teacher's mental or espoused models of teaching and learning mathematics are subject to the constraints and contingencies of the school context, and they are transformed into classroom practices. These are: the enacted (as opposed to espoused) model of teaching mathematics, the use of mathematics texts or materials, and the enacted (as opposed to espoused) model of learning mathematics. Ernest believes that the espoused-enacted distinction is necessary because case-studies have shown that there can be a great disparity between a teacher's espoused and enacted models of teaching and learning mathematics (for example, Cooney (1985)).

Ernest points out two main causes for the mismatch between beliefs and practices. Firstly, there is the powerful influence of the social context, as the results from the expectations of others including students, parents, peers (fellow teachers) and superiors, and the institutionalized curriculum (the adopted text or curricular scheme), the system of assessment, and the overall national system of schooling. The socio-cultural norms (Yackel and Cobb, 1996), established within the social and cultural contexts of the teaching situation, determine the teachers' practices. These can be viewed as a set of constraints that can affect the enactment of the models of teaching and learning mathematics. In addition, Ernest also places the importance on the socialization effect of the context that can very powerful that despite having different beliefs about mathematics and its teaching, teachers in the same school are often observed to adopt similar classroom practices.

Secondly, there is the teacher's level of consciousness of his or her own beliefs, and the extent to which the teacher reflects on his or her practice of teaching mathematics. Ernest points out some of the key elements in the teacher's thinking and its relationship to practice:

- Awareness of having adopted specific views and assumptions as to the nature of mathematics and its teaching and learning
- The ability to justify these views and assumptions
- Awareness of the existence of viable alternatives
- Context-sensitivity in choosing and implementing situationally appropriate teaching and learning strategies in accordance with his or her own views and models
- Reflexivity: being concerned to reconcile and integrate classroom practices with beliefs; and to reconcile conflicting beliefs themselves

Ernest believes that these elements of teacher's thinking are likely to be associated with some of the beliefs mentioned previously in this paper. For example, the adoption of the role of facilitator in a problem-solving classroom requires reflection on the roles of the teacher and learner, on the context suitability of the model, and probably also on the match between beliefs and practices. On the other hand, the instrumental view and the associated models of teaching and learning requires little self-consciousness and reflection, or awareness of the existence of viable alternatives.

Lastly, Ernest briefly summarizes the impact of beliefs on the teaching of mathematics as follows:

> I have argued that mathematics teachers' beliefs have a powerful impact on the practice of teaching. During their transformation into practice, two factors affect these beliefs: the constraints and opportunities of the social context of teaching, and the level of the teacher's thought. Higher level thought enables the teacher to reflect on the gap between beliefs and practice, and to narrow it. The autonomy of the mathematics teacher depends on all three factors: beliefs, social context,

> and level of thought. For beliefs can determine, for example, whether a mathematics text is used uncritically or not, one of the key indicators of autonomy. The social context clearly constrains the teacher's freedom of choice and action, restricting the ambit of the teacher's autonomy. Higher level thought, such as self-evaluation with regard to putting beliefs into practice, is a key element of autonomy in teaching. Only by considering all three factors can we begin to do justice to the complex notion of the autonomous mathematics teacher. (p. 254)

3.3 Research Questions

The theories and literature presented in this Chapter and in Chapter 2 on assessment and teachers' beliefs and practice are predominantly presented from the school context. Although they come from the school context, these theories about the relationship between beliefs and practice apply equally to the university context.

It is also important for me to add that most of my literature review writing was finished prior to year of 2015. Even though the literature review in my thesis was only prior to year of 2015, I did stay up to date with the most current research papers on beliefs about mathematics assessment and practice, and oral assessment in mathematics that have been published since then. Since 2015, I did not find any new research findings on beliefs about mathematics assessment and practice, and oral mathematics assessment that could be applicable for my research topic, or that was already not presented in my thesis. Therefore, although the literature cited only goes up to 2015, there were no relevant literature between 2015 to present.

The lack of research studies on mathematics professors' beliefs and practice from an oral assessment perspective led me to the main research question of this thesis, which is: "*What factors influence mathematics professors' views on oral assessment in mathematics?*"

More specifically, this primary question breaks into the set of following questions:

1. *What are the mathematics professors' views on written assessment in mathematics?*
2. *What are the mathematics professors' views on oral assessment in mathematics?*

3. *What are the mathematics professors' views on their mathematics assessment practice?* This would include their espoused and enacted assessment practices in mathematics classrooms.

Chapter 4

Methodology

In order to answer the research questions, I needed to look for participants who were currently teaching in an environment where their assessment practices were different from the ones they experienced when they were students. More specifically, I needed to look for: mathematics professors who were educated in a culture where oral assessment in mathematics was an important part of assessment practice in mathematics, and they are currently teaching in a culture where oral assessment in mathematics is not part of the system of education; and, mathematics professors who were educated in a culture where oral assessment in mathematics was not part of the system of education, and they are currently teaching in a culture where oral assessment in mathematics is an important part of assessment practice in mathematics. Throughout this thesis, I will be referring to the first group of participants as participants who were educated in an oral assessment culture, and they are currently teaching in a written assessment culture. Similarly, I will be referring to the second group of participants as participants who were educated in a written assessment culture, and they are currently teaching in an oral assessment culture.

As the Canadian educational system is dominated by closed-book, written examinations, and oral assessment is not common in mathematics departments in Canada, finding the first group of participants was easier than the second one.

This chapter is composed of two parts. The first part is dedicated to a description of the participants and the process of their recruitment. The second part contains description of the research design used for data collection and analysis.

4.1 Recruitment of Participants

In terms of recruitment, I used a methodology of snowball sampling, a technique for finding research subjects, in which one subject gives the researcher the name of another subject, who in turn provides the name of a third, and so on (Vogt, 1999). Therefore, I started with mathematicians whom I knew professionally, and then asked them to recommend others in the mathematics department or elsewhere, for whom they suspected that they may have a history of experiencing of using oral assessment. Thus, selection of the participants was based on the following criteria: each participant has been exposed to oral assessment in mathematics either as a student and/or as a professor. This criteria for selection was applied to both groups of participants, namely to participants who were educated in oral assessment culture, and who are currently teaching in a written assessment culture, and to participants who were educated in written assessment culture, and who are currently teaching in an oral assessment culture.

4.1.1 Participants

Seven mathematics professors and instructors were selected for the interviews: Melissa, Elisabeth, Van, Nora, Dave, James, and Jane. These names are pseudonyms. Melissa, Elisabeth, Van, and Nora, who were born and educated in Poland, Romania, Bosnia, and Ukraine, respectively, are currently teaching at a Canadian university while Dave, James, and Jane, who were born and educated in Canada, Germany, and the United States, respectively, are currently teaching at a university in Germany. With respect to familiarity with oral assessment, Van, Melissa, Nora, and Elisabeth had been previously exposed to oral examinations in mathematics before moving to Canada, while Dave and Jane, who were educated in Canada and the United States, had never been exposed to oral examination in mathematics before moving to Germany. James was born in Germany, but educated both in Germany and in the United States, and thus, he has had a lot of exposure to oral assessment in mathematics.

Melissa, Elisabeth, Van, and Nora were the first group of participants who were recruited for this study. The first three participants I knew professionally as we all work in the

same mathematics department at the same university campus. Nora also works in the same mathematics department as the other three participants, but teaches at a different university campus, so I did not have a chance to meet her prior to the interview. She was recommended by Melissa. They both taught the same mathematics courses in the past. All four participants know each other professionally.

The second group of participants, Dave, James, and Jane, also work at the same university, in a mathematics department, but in Germany. Dave was recommended by my senior supervisor. They know each other professionally. Then, Dave recommended James, and he recommended Jane.

The detailed description of each participant is provided below in Table 4.1:

Table 4.1: Description of Participants

Participant	**Education**	**Past Position**	**Past Teaching**	**Current Position**	**Current Teaching**
Melissa	Bachelor; Master; PhD in Pure Mathematics (Poland)	Mathematics Teaching Assistant; Mathematics Instructor	Calculus; General Mathematics for Librarians; Mathematical Logic for Teachers	Mathematics Lecturer	Calculus; Pre-Calculus; Discrete Mathematics; Mathematics for Elementary School Teachers; Foundations of Analytical and Quantitative Reasoning
Elizabeth	Bachelor; Master in Pure Mathematics (Romania); PhD in Mathematics Education (Canada)	Mathematics Instructor	Pre-Calculus; Calculus; Advance Algebra; Statistics and Probability	Mathematics Instructor	Calculus; Foundations of Analytical and Quantitative Reasoning

Participant	Education	Past Position	Past Teaching	Current Position	Current Teaching
Van	Bachelor in Mathematics (Bosnia); Master in Mathematics (Croatia); PhD in Mathematics (Canada)	Mathematics Teaching Assistant; Mathematics Instructor	Calculus I; Calculus II; Calculus III; Differential Equations	Mathematics Teaching Professor	Calculus; Pre-Calculus; Differential Equations; Discrete Mathematics; Mathematical Analysis; Undergraduate Math Seminar; Foundations of Analytical and Quantitative Reasoning
Nora	Bachelor; Master; PhD in Mathematics (Ukraine)			Mathematics Lecturer	Calculus; Pre-Calculus; Discrete Mathematics; Differential Equations
Dave	Bachelor in Mathematics; Master in Mathematics Education (Canada); PhD in Mathematics Education (Canada)	Mathematics Teaching Assistant; Mathematics Instructor	Mathematics Education Courses	Mathematics Professor	Mathematics Education for Experienced Teachers; Mathematics for Future Primary School Teachers

Participant	Education	Past Position	Past Teaching	Current Position	Current Teaching
James	Bachelor in Mathematics (Germany); Master in Mathematics (USA); PhD in Mathematics (USA)	Mathematics Teaching Assistant; Mathematics Instructor	Calculus; Differential Equations; Other Lower and Higher Mathematics Division Courses	Mathematics Professor	Variety of Mathematics Courses
Jane	Bachelor; Master; PhD in Mathematics (USA)	Mathematics Teaching Assistant		Mathematics Professor	Mathematics for Engineering and Environmental Physics Master Students; Other Master's Level Advanced Mathematics Courses

4.2 Data Gathering

Data for this study consist of the transcripts of individual interviews. More detailed methods of data collection are discussed in what follows.

4.2.1 Interview Questions

The participants' interviews had four purposes:

- to identify the ways in which mathematics professors experience and view oral assessment, written assessment, and mathematics assessment practice;

- to identify the aspects of oral and written assessment that appear to be important to mathematics professors;
- to identify the oral and written assessment limitations;
- to identify the aspects of teaching and studying in oral and written assessment cultures.

The interview's open-ended questions were created according to these four purposes, in order to gather information about participants' personal experiences and perspectives on using written and oral assessment in mathematics classroom during their schooling and teaching in oral and written assessment cultures. In other words, during participants' teaching outside of Canada or Germany and in Canada or Germany.

Therefore, the interview questions were divided into three groups:

- participant as being a student;
- participant as being a professor outside of Canada or Germany;
- participant as being a professor in Canada or Germany.

The first set of questions focused on the participants' experiences with mathematics assessment as a student:

- Where did you complete your undergraduate/graduate studies?
- What kind of exams did you have in your mathematics courses during your studies?
- Was the oral assessment used during your studies in your mathematics courses, and in which form?
- How was the oral assessment conducted?
- How did you prepare for oral assessment?
- How did you feel about oral in comparison to written exams?
- As a student, which form of examination did you prefer and why?

The second set of questions was based on the participants' experiences with mathematics assessment teaching outside of Canada or Germany:

- Where did you teach mathematics before teaching in Canada? For how long?
- Which mathematics courses did you teach, at what level, and what was the average class size?
- What types of assessment did you use in teaching mathematics?
- Did you use the oral assessment? If yes, how did you conduct the oral assessment in your mathematics classroom?
- How did you deal with cheating during exams? Was it a problem?
- Do you think that students would study in a different way if cheating was impossible?
- Did you experience any issues during the oral assessment process, for instance, time management, students' anxiety, etc.?
- How long did it take you to assess one class during the oral exam?
- How did your students feel about taking oral exams in comparison to written exams?
- Is there something that students learn from doing a test orally that they would not learn from a written test and vice-versa?
- How did you ensure objectivity and evidence for the justification of grading? Did you use the oral assessment rubric for grading?
- In your opinion, what are the advantages and disadvantages of oral exams in comparison to written exams?
- Could these tests be done in a better way? If yes, how?

The third set of questions focused on the participants' experiences with mathematics assessment teaching in Canada or Germany:

- Where are you currently teaching? For how long? What mathematics courses? Average class size?
- Do you use (have you tried to use) the oral assessment in your current mathematics courses? If not, why not?
- If you are about to implement (or discontinue) oral assessment in your current mathematics courses, what could you predict?
- What kind of examination do you personally prefer? Why?
- Could your current assessment that you are implementing in your mathematics courses be done in a better way? If yes, how?
- Would you be able to recommend me someone who has also been exposed to oral assessment, either as a student and/or as a professor, and be willing to get interviewed?

Before the interviews were conducted, each participant was provided with a consent form via email, agreeing to participate in this research study. Also, each participant was provided with a copy of the interview questions via email prior to an interview, and all the interviews were scheduled and arranged via email. The interview questions were asked in the same order as they were presented above. The interviews were structured in a way that no further discussion occurred during the interviews, no other questions were asked during the interviews but the one that the participants were provided with, and no follow up questions were asked to participants after the interviews.

The interviews with Melissa, Elisabeth, Van, and Nora were conducted in their offices at the university where they are currently teaching while the interviews with Dave, James, and Jane were conducted via Skype. Each participant was interviewed only once, and all interviews were conducted during the months of May, June, and July of 2016. The participants were interviewed in the following order, starting from the first to last: Melissa, Elisabeth, Van, Nora, Dave, James, and Jane. The interviews were audio-recorded, and each interview lasted for about an hour. The audio recordings of interviews were transcribed, and transcriptions were used for data analysis.

4.2.2 The Data Analysis

The research design for this study is qualitative. I chose the qualitative research method for data collection and analysis because this thesis focuses more on in depth understanding of mathematics professors' beliefs about mathematics assessment and mathematics assessment practice from various schooling and teaching cultures. It focuses on the origin of these beliefs, and how these beliefs affect mathematics professors' teaching and assessment practices.

After I transcribed the audio recordings of interviews, I tried to look for possible patterns based on provided answers. By looking for the patterns throughout the data, I wanted to identify some shared views among participants, which could help me in defining the themes for discussing and organizing the results of the data.

The purpose of this thesis is to examine the relationship between mathematics professors' views on written and oral assessment in mathematics, and their mathematics assessment practice. In order to achieve this goal, I modified the original model from Ernest (1989), presented in Chapter 3 (section 3.2) by adding Espoused and Enacted Models of Mathematics Assessment (see right hand side of Figure 4.1).

Ernest (1989) believes that the system of assessment can be viewed as one of many sets of constraints that can affect the enactment of the models of teaching and learning mathematics, but he does not specifically state if the model of mathematics assessment falls under learning or teaching model particularly. Therefore, in this study, the model of mathematics assessment is to be viewed as a separate entity.

This modified diagram shows how mathematics professors' views of the nature of mathematics and mathematics assessment provide a basis for the professors' mental model of mathematics assessment. This professor's mental or espoused model of mathematics assessment is subject to the constraints and opportunities of the university context, and it is transformed into classroom practices. This is the enacted (as opposed to espoused) model of mathematics assessment.

Moreover, this modified diagram served as a theoretical framework for analyzing the data, and it helped in establishing the themes for organizing the data. Therefore, the participants' experiences with mathematics assessment are discussed in the context of the

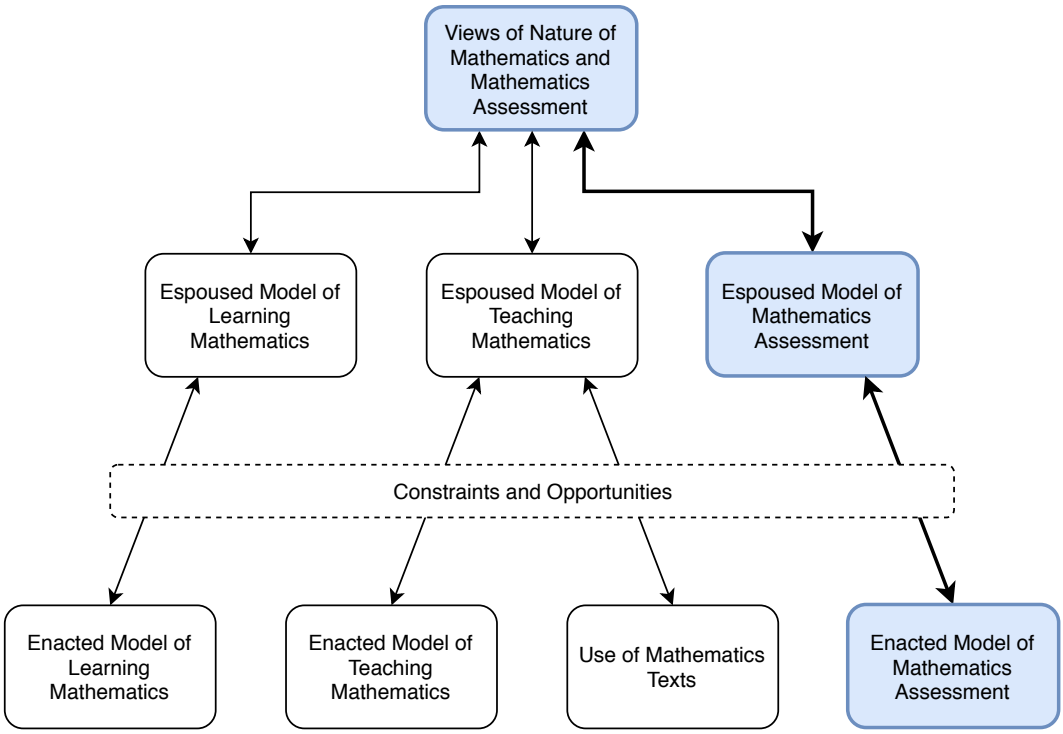

Figure 4.1: Modified Version of Figure 3.1: Relationships Between Beliefs, and Their Impact on Practice

following six themes: espoused beliefs about mathematics, espoused beliefs about mathematics assessment, espoused beliefs about written mathematics assessment, espoused beliefs about oral mathematics assessment, constraints and opportunities of the teaching context, and enacted mathematics assessment practice. These themes are presented in Figure 4.2.

After identifying these six themes, the following more specific themes were used for organizing the results of this thesis in the order presented below:

- espoused beliefs about mathematics and mathematics assessment;
- espoused beliefs about written assessment in mathematics;
- espoused beliefs about oral assessment in mathematics;
- tensions in espoused beliefs about oral and written assessment in mathematics;
- clusters of espoused beliefs and their relationships;
- constraints and opportunities of the teaching context and the socio-cultural norms;

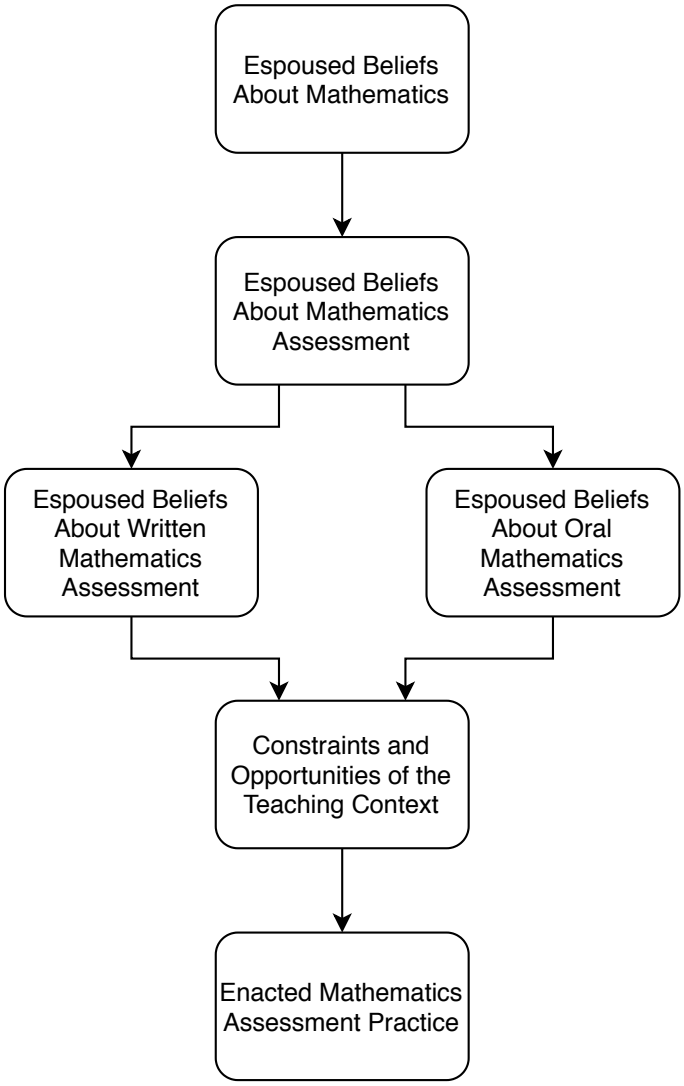

Figure 4.2: Relationships Between Espoused Beliefs of Written and Oral Assessment in Mathematics, and Enacted Mathematics Assessment Practice

- enacted mathematics assessment practice;
- concerns with implementing and discontinuing oral assessment in mathematics.

In terms of identifying clusters of espoused beliefs, these groups of beliefs were identified based on their relationships between participants' espoused beliefs about mathematics and mathematics assessment, specifically written and oral mathematics assessment. The interpretation of these groups was based on Green (1971) concepts of beliefs systems: primary and derivative (a belief that is derived from a primary belief).

When it comes to identifying constraints and opportunities that exist within the participants' teaching context, these were organized and analyzed based on the socio-cultural norms (Yackel and Cobb, 1996), established within the social and the cultural contexts of the teaching situation, which determine the participants' enacted mathematics assessment practices and their practice of teaching mathematics.

Chapter 5

Relationship between espoused beliefs and enacted mathematics assessment practice

This chapter discusses and presents the findings according to the following themes that were presented in Chapter 4:

- espoused beliefs about mathematics and mathematics assessment;
- espoused beliefs about written assessment in mathematics;
- espoused beliefs about oral assessment in mathematics;
- tensions in espoused beliefs about oral and written assessment in mathematics;
- clusters of espoused beliefs and their relationships;
- constraints and opportunities of the teaching context and the socio-cultural norms;
- enacted mathematics assessment practice;
- concerns with implementing and discontinuing oral assessment in mathematics.

5.1 Espoused Beliefs about Mathematics and Mathematics Assessment

The participants' espoused beliefs about mathematics and mathematics assessment are presented in Table 5.1a and Table 5.1b. The words highlighted in italics in Table 5.1a and

Table 5.1b are the common words identified in the participants' shared responses about their espoused beliefs about mathematics and mathematics assessment. These commons words are: 'understanding,' 'knowing,' 'application,' 'thinking,' 'reasoning,' 'concept,' and 'procedure.'

	Definition	**Participants**
Mathematics is	*Knowing* theory and *application*	Nora; Melissa; Elisabeth
	A way of *thinking* about things	Dave; Van
	Art of working with abstract *concepts* towards their *understanding*	James
	Pattern recognition	Jane; Nora

Table 5.1a: Espoused Beliefs about Mathematics

	Definition	**Participants**
Mathematics assessment should	Assess *reasoning*, logical *thinking*, and *understanding* of the *concept* and *procedure*	Melissa; Van; Jane; Nora
	Promote discussion	Elisabeth
	Sort out future mathematics teachers who are good and not good in mathematics	Dave
	Assess recipe mathematics to non-mathematics major students and *conceptual* mathematics to mathematics major students	James

Table 5.1b: Espoused Beliefs about Mathematics Assessment

When it came to the participants' espoused beliefs about mathematics, it seemed that most of the participants' beliefs about mathematics were in relation to knowing and understanding the mathematical concepts and their applications. Similarly, when it came to the participants' espoused beliefs about mathematics assessment, what most of the participants valued about mathematics assessment was the ability to assess students' reasoning and understanding of the concepts and procedures.

An interesting comment came from Dave when he talked about his beliefs on what would be the main purpose of mathematics assessment in his mathematics course for future school teachers that he teaches in Germany:

> If you like, the primary function of my assessment isn't to tell anybody how good they are at math. It is to sort out people who are bad at it. And in the best of all possible worlds, I would like to say well you're only bad at it because you had ten years of bad math teaching in school and so we'll just try and fix that. But my experience is that it takes more than ten weeks to fix ten years of bad teaching.

The participants' espoused beliefs about mathematics assessment are based on their prior schooling and teaching experience, the school culture, and the study program within the assessment culture. Oral examinations in mathematics were part of the educational system in some of the participants' prior schooling and teaching experience, therefore, the oral exams were considered to be an essential and natural part of the examination process, from primary to higher education. Melissa, James and Jane exemplified this:

> We were used to, it was natural. It was not something that different in high school, it was a continuation of high school. (*Melissa*)

> Mathematics I think very much lives from discussions. So, for me the oral examination is much more natural, and the written examination is just out of necessity. (*James*)

> I have reasons that I feel are good reasons that I prefer written exams, but, you know, maybe I wouldn't think those things if I had gone through a system with oral exams. (*Jane*)

Another reason for believing that the oral exams play an important part in the assessment process in mathematics was related to the culture and the study program in the university where they are teaching. James explained this:

> This is natural because it had this effect of getting to know those students who will continue into the higher level diploma courses, so much like you would get to know those master students so to speak that come after.

On the other hand, the oral exams can cause discomfort to those who had never been exposed to it, as being something that is not completely natural or familiar. Dave exemplified his view on the possibility of using the oral exams:

> It is primarily I guess if you like a cultural issue [. . .] I think there is going to be a difference between me doing an oral exam and somebody who has grown up with oral exams doing an oral exam [...] I'm doing something that is not part of my cultural background that I don't have any intuitions about it even if I have knowledge about it.

An interesting finding came from the participants' responses in relation to the questions that they were asked, specifically putting the emphasis on the word 'assessment.' Therefore, when the participants were asked 'What kind of assessment are they currently using in their mathematics courses?,' Van, Melissa, Elisabeth, and Nora all used word 'assessment' in their responses while Dave, Jane, and James all responded with using words 'exam' and/or 'examination' instead. On the other hand, when the participants were asked 'What kind of assessment were they exposed to in their mathematics courses before coming to Canada and Germany?,' Van, Melissa, Elisabeth, Nora, and James all responded with using words 'exam' and/or 'examination' while Dave and Jane both used word 'assessment' in their responses. Even though both questions emphasized what is the 'assessment' that the participants are currently using or used in the past, words 'assessment,' 'exam,' and 'examination' were interchangeably used depending on the participants' current or past experiences with mathematics assessment. It seems that the participants who responded with 'assessment,' their current or past experiences consisted of using multiple forms of written assessment in mathematics, such as mid-term exam, final exam, quizzes, homework assignments, online assignments, participation, essays, reflections, etc. On the other hand, the participants who responded with 'exam/examination,' their current or past experiences

with mathematics assessment consisted of using only written and oral exams, as the only two forms of assessment that count for students' final grades.

5.2 Espoused Beliefs about Written Assessment in Mathematics

The participants' espoused beliefs about written assessment in mathematics can be divided between the positive aspects and the negative aspects of written assessment in mathematics.

5.2.1 Positive Aspects

Based on the positive aspects, written assessment in mathematics:

- Allows the relation only between the student and the subject that is being assessed
- Provides an opportunity to answer questions in order of student's preference
- Provides a written record of student's performance

Allows the relation only between the student and the subject that is being assessed

Melissa explained this when she was asked to describe some of the positive characteristics of written assessment:

> I probably had the slight preference for written because this was only between me and subject.

Provides an opportunity to answer questions in order of student's preference

Jane exemplified this based on her experience with using the written assessment in mathematics courses during her previous education:

> When you have a written exam, you have a choice of answering questions in different order, then you really have time.

Provides a written record of student's performance

Jane also mentioned that one of the positive aspects of written assessment is that during the written exams there is a written record or a proof of students' work. She explained:

> When you have a written exam, there is this record of like completely detailed record about what happened on the exam, then the student has some sort of form of recourse if they feel they weren't graded correctly. And it's there, it's written.

5.2.2 Negative Aspects

Based on the negative aspects, written assessment in mathematics:

- Does not prevent plagiarism
- Does not provide an opportunity to redeem
- Limits an examiner to assess a wide range of student's knowledge and understanding of the subject

Does not prevent plagiarism

When the participants were asked if it is possible for students to cheat during the written exams, Melissa responded:

> It was possible because in a way in a large room that possibly somebody would bring a piece of paper with something.

Does not provide an opportunity to redeem

According to Elisabeth and Nora, when there is only a written exam, then there is no opportunity for students to have another chance to redeem themselves in case if they do not do well on the written exam. They explained:

> Sometimes when there is only a written exam, so some people may claim, "Oh, I knew it, but I got stuck," or "I had a bad day, and everything was in that exam." (*Elisabeth*)

> You have no chance to redeem yourself if accidentally you had a bad luck of getting the questions exactly in the areas where you are not the best. (*Nora*)

Limits an examiner to assess a wide range of student's knowledge and understanding of the subject

Nora explained this when she was asked to describe some of the negative characteristics of written assessment:

> First of all, written exam can test some parts, but not everything of what you have studied.

5.3 Espoused Beliefs about Oral Assessment in Mathematics

When it comes to the participants' espoused beliefs about oral assessment in mathematics, they can also be divided between the positive aspects and the negative aspects of oral assessment in mathematics.

5.3.1 Positive Aspects

Based on the positive aspects, oral assessment in mathematics:

- Is reactive to student's needs in terms of providing an opportunity for discussion, followup questions, and instant feedback
- Reaffirms/improves students' grades
- Prevents plagiarism
- Provides an opportunity for students to assess themselves by listening their classmates
- Can assess students' thinking
- Provides an opportunity to redeem
- Allows differentiated assessment
- Provides an opportunity to adapt the level of questions to each student's level of response

Is reactive to student's needs in terms of providing an opportunity for discussion, followup questions, and instant feedback

Melissa and Elisabeth exemplified this when they were asked to describe some of the positive characteristics of oral assessment:

> It was this instant feedback and the possibility of follow-up questions or discussion, and sometimes it was also discussion because in cases when the instructor felt that you're doing a good job that you had an opportunity actually for some sort of exchange. Sometimes it felt more rewarding experience that just a written one. (*Melissa*)

> So, you would submit an assignment, and maybe you get it back one week or maybe later than one week after that, and maybe you don't care anymore, and maybe you have read the solutions that are possible and then you don't care about comparing with your work and fixing your mistakes or something like that. But when you have an oral examination, maybe you will work on that instantaneously. In this idea of learning from your mistakes, I think it is more valuable in the oral examination or in the oral conversation. (*Elisabeth*)

Reaffirms/improves students' grades

Melissa commented that the oral assessment not only provides an opportunity for students to confirm their knowledge and understanding of the material, but also usually provides an opportunity for students to improve their course grades:

> I felt that it was generally an opportunity to reaffirm or correct your written examination. And, I felt that in most cases it was, in practically all cases, that it was reaffirming or improving the grade.

Prevents plagiarism

In terms of cheating during the oral exams, Melissa, Elisabeth and Van all expressed their own opinions based on their experiences with using the oral exams in mathematics courses during their previous teaching and schooling:

> Well, you did not have access to any of your notes or anything. In theory, you could have somebody else substituting for you, but I've never heard of anything like this. I don't remember whether there were any ID's checked when entering. This, I don't remember. I don't see how you can cheat during the oral. (*Melissa*)

> I don't think they can cheat. When you step in front of an examiner, if the student has the topic on the notes, so sometimes, yeah, some people could cheat in that time given before stepping into the oral examination, so they could get access to notes and write something on that paper. But, once you are in front of the examiner, once you are in the out, what is on the paper through the process of discussion of question and answer, you can see if the student got access to that special formula. (*Elisabeth*)

> You cannot cheat on the oral exam. That was my always experience, and for good or bad, I mean on the oral exam you are on your own. (*Van*)

Provides an opportunity for students to assess themselves by listening their classmates

Elisabeth explained this when she talked about her experience during the oral examination as being a student:

> That was a very good way to know where each and everyone stands because in college, and elementary and high schools, everybody used to be there, and the examination is in front of the entire class.

Can assess students' thinking

Elisabeth also mentioned that one of the positive aspects of oral assessment is that it provides an opportunity for students to show their thinking process about the material that is being assessed. She commented:

> That line of thinking that is something that we can assess through the oral examination.

Provides an opportunity to redeem

If there is an oral exam, then there is an opportunity for students to have another chance to redeem themselves in case if they do not do well on the written exam. Nora explained:

> What was fantastic about it, what I really loved, is that you had a chance to redeem yourself, because some students get really scared when they get a question. I have seen it. They get frozen. They stop writing. Some are so jittery. I have seen it all, here. There, if it happens to you, even if you come with a blank sheet of paper to the professor, they can start talking to you, and within 5 minutes you calm down normally. They would ask you, "Okay, so what do you say on this? What is the theorem? Okay, what do you recall? You forgot the proof. Okay. So, can you tell me the actual theorem? Okay. Where do you start in this theorem?"

Allows differentiated assessment

With the oral assessment, students also have an option to show and present their knowledge and understanding of the material orally, not just through the writing. Dave explained:

> The advantage that I can see is that the written exam format is one format of assessment and not everybody is equally good at dealing with that format. So, in general, in assessment, it is understood that multiple forms of assessment are better than a single form of assessment. Because then the format of the assessment is having less of a weight on the outcome. So, then it would make sense for everybody to have a mixture of oral, written performance, different kinds of assessment in every course, but that doesn't happen. And in courses with hundreds of people, I can imagine it would get quite complicated.

Provides an opportunity to adapt the level of questions to each student's level of response

During the oral examination, an examiner is able to adjust the exam questions according to the student's knowledge and the ability to answer the question. James and Elisabeth exemplified this:

> In the oral exams, I get to know the person better, how he or she thinks, and I can very much adapt the level of questions to the level of response. This allows me for instance, from the homework, if I have the impression this is a really good person, I would start out asking difficult questions to allow him or her to get an A. And, for other people who I don't really know, I would also start high level, but not very high and then see whether I can go towards an A question or go towards a question that just gives a D or something. So, this flexibility is what I very much value in oral exams, but at the same time it involves subjective decisions. (*James*)

> So usually starting from one question, one problem or one exercise and then if that was going nicely, correctly, fluently, maybe all was good. But if the student will stumble and not be able to do it, then giving them easier and easier questions to solve because if somebody is stuck at some topic, maybe if they cannot do the derivative, you have to see if they can do limits, and if they cannot do limits, you have to get lower and so. It takes time. (*Elisabeth*)

5.3.2 Negative Aspects

Based on the negative aspects, oral assessment in mathematics:

- Can make the students feel intimidated or discriminated by an examiner

Can make the students feel intimidated or discriminated by an examiner

Van, Elisabeth, Nora and Melissa shared their personal experiences with oral exams as being students. Van and Elisabeth commented that during the oral examination some professors would even mock a student if he/she is not well prepared for the exam. They explained:

> One thing that I didn't like about oral exam was that there were people that were misusing their powers over students. And, some kind of verbal abuse in front of your peers that we cannot even imagine here in Canada. Yeah, making fun of somebody that he/she feels stupid in front of twenty, thirty people was a

> regular, and, also, I mean there were extreme cases that sadly I'm aware of that some instructors were just corrupted. (*Van*)

> Sometimes in Romania they could make fun of you even in university. Professors, yeah when writing something really wrong. If there was something wrong with some of the basics and you got it incorrect or something like that. Yeah, they would make fun of you. (*Elisabeth*)

Nora talked about how she felt being discriminated in mathematics class as a female student:

> Discrimination of some sort was going. I was a victim of discrimination myself because I was in the math department, but that was a subsection, which was more towards the engineering mathematics. And some of the professors were very old school, old gentleman, like 70, I would say plus. In their opinion, a girl could never get an A. So, I challenged that with a professor. I asked him, "Okay, if you think that I'm not getting the level, ask me as much as you want. Four hours." After that, I had the reputation 'don't touch her' because if I know that I know, they cannot do anything to me.

Melissa also had similar experience during her schooling:

> There were a couple of those which I felt I've been too intimidated, but overall it was a positive experience. It was because of the feeling that the examiner is sort of this inaccessible person, which is just examining me and not [...] yes, so it is not somebody I would be free to ask questions. So, intimidation was often related to the personality of the instructor.

5.4 Tensions in Espoused Beliefs about Oral and Written Assessment in Mathematics

There are tensions that exist in the participants' espoused beliefs about written and oral assessment in mathematics when it comes to fairness, lack of time to conduct the oral

exams, students' anxiety in oral and written exams, and assessing knowledge and understanding in oral and written exams. The first three tensions in case of fairness, lack of time, and students' anxiety are discussed in what follows based on Green's (1971) classification of *evidential* and *non-evidential* beliefs. *Evidential* beliefs are beliefs that are held on the basis of evidence or reasons and can be modified in the light of further evidence or better reasons while *non-evidential* beliefs are held without regard to evidence, or opposite to evidence, or apart from good reasons and cannot be modified by introducing reasons or evidence. When it comes to the fourth tension, assessing knowledge and understanding in oral and written exams, based on the participants' responses on what can be assessed in oral and written exams in mathematics, there was a clear division between the beliefs of participants who had previously been exposed to oral assessment in mathematics and the one who had not. This division of beliefs is discussed in terms of two types of knowledge and understanding in mathematics introduced by Skemp (1976), and Hiebert and Lefevre (1986). Skemp (1976) classified two types of understanding in mathematics, *relational understanding* as knowing both what to do and why, and *instrumental understanding* as the ability to execute mathematical rules and procedures. Also, Hiebert and Lefevre (1986) introduced two types of knowledge in mathematics, *conceptual knowledge*, a knowledge rich in relationships, and *procedural knowledge*, a knowledge that consists of rules or procedures for solving mathematical problems knowledge.

In the following sub-sections, the above described four tensions are discussed.

5.4.1 Fairness

Based on the participants' responses, it is still not quite clear which type of an exam, oral or written, can be considered to be more or less fair in comparison to each other. When it comes to the question of fairness, the beliefs were divided between the following: the oral exams can be perceived as less fair than the written ones, and that there is no ideal assessment. Elisabeth exemplified the first point, and Nora exemplified the second one:

> It may look like [...] in written exam everybody writes the same questions, right? But in the oral, there are different topics, different sections, so [. . .] at least when I was a student, somebody could draw a card with a topic from chapter two and

> somebody with chapter thirteen and maybe that person didn't go that far as to study chapter thirteen. (*Elisabeth*)

> There is still debatable fairness because even if I have four TAs marking the same question, believe me, if I remark later, disparity, four percent or five percent. So, nothing is bulletproof [...] you cannot make guarantee that all will be extremely fairly assessed. (*Nora*)

The participants who had been previously exposed to oral exams in mathematics, Melissa, Elisabeth, Van, Nora, and James, believed that there is a written record or a proof of students' work during the oral exams as each student would have a scrap paper with his/her work on it that would be collected at the end of an exam by the examiner. This type of belief can be considered as *evidential belief*. Nora exemplified this when she talked about her experience with conducting an oral exam in one of her undergraduate mathematics courses that she was teaching in Ukraine:

> The room was quite big so they would be sitting at some distance. There was completely no chance to cheat. You're sitting four or five meters away from another person. You were not allowed to come with any bags or anything. So, it was out of question. You come, the instructor would give you a sheet of paper. You cannot bring anything with you. Pen, pencil. That's it.

On the other hand, the participants who had never been exposed to oral exams in mathematics, Dave and Jane, believed that there is no written record or a proof of students' work during the oral exams. Their belief is probably based on their lack of experience with oral exams. Therefore, this type of belief can be considered as *non-evidential* belief. Jane explained her point:

> With the oral exam you are kind of just taking notes, maybe there is a second person in the room who is taking notes, but it is kind of a sketch of what is going on.

5.4.2 Lack of Time

When it comes to an issue of lacking time to perform the oral exams, it was interesting to see that the majority of the participants believed that because of the large class sizes in their mathematics courses, it is difficult for them to find the time to perform the oral exams. This can be also considered as *non-evidential* belief for two reasons. The first reason has to do with the fact that those participants who are currently teaching in Canada spend a quite amount of time assessing students in their mathematics courses, using different forms of written assessment. Therefore, if there is a belief that the lack of time can be an issue for conducting the oral exams, then how is it possible to find the time to assess students very frequently? Elisabeth exemplified this when she talked about her current assessment experience with one of her undergraduate mathematics courses that she teaches in Canada:

> So sometimes in Foundations of Analytical and Quantitative Reasoning course for example somebody looking from the outside may say 'oh you're assessing them so much' because we have ten written quizzes, ten homework assignments, many LONG CAPA quizzes. Every week there is a LONG CAPA quiz and two mid-terms and the final exam. So in the end the final grade is out of thirty, thirty-four grades or something like that, so someone from the outside will say 'what are you doing? Why are you assessing them so much?'

The second reason is due to the large class sizes in mathematics courses. The question that I raised here was: Does class size really matter for conducting the oral exams? The reason why I raised this question was because when I was comparing the participants' average mathematics class sizes that they are currently teaching with average mathematics class sizes during their undergraduate studies and/or their prior teaching, I realized that the numbers were quite similar. These numbers are shown in Table 5.2. The participants' mathematics classes that they are currently teaching are represented in Table 5.2 as Lecture A, Lecture B, and Lecture C. Each of these three classes illustrates the number of students enrolled in them where only written assessment is used. The column that represents the past average class size illustrates the number of students enrolled in mathematics courses where oral assessment was used in addition to written assessment.

Participant	Average Class Size (Past-Oral & Written)	Average Class Size (Present-Written)		
	Lecture	Lecture A	Lecture B	Lecture C
Dave	-	80-150		
Elisabeth	120	30-35		
Jane	-	3		
Melissa	240	200-300	80-150	30-40
Nora	100-125	100-500		
Van	120	100-500	25	60

Table 5.2: Past and Present Average Mathematics Class Size

There was no strong evidence here that showed whether the number of students could be an important factor for conducting the oral exams in mathematics. It seemed that despite of the large classes, the oral exams still played an important part in assessing students in mathematics for those who strongly favored them. For instance, despite having only three students in class, Jane was someone who strongly disfavored oral exams, even though she had such a small class, which would be perfectly doable for conducting the oral exams, she was strictly relying on the written exams solely. Thus, this showed that the way Jane viewed mathematics assessment strongly affected how her mathematics classes were assessed regardless of their sizes. Moreover, according to Green (1971), beliefs that are held non-evidentially cannot be modified by introducing reasons or evidence neither they can be changed by rational criticism, thus, Jane's non-evidential beliefs about oral assessment could not be modified even if she was provided with the evidence or reasons. The data clearly show that non-evidential beliefs can influence the views on oral assessment in mathematics.

5.4.3 Students' Anxiety

Based on the participants' responses, it is not clear which type of an exam, oral or written, can cause more or less anxiety among students. In terms of students' anxiety in oral and written exams, the beliefs were divided between the following: the level of anxiety would be higher in oral than written exams, and that it would be hard to determine which type of an exam can cause more or less anxiety among students. Van and Elisabeth explained the first point related to the higher level of anxiety in oral exams:

> So, there is a quite bit of pressure to perform in a short period of time and that's not easy [...] I believe with oral exam there is a higher level of anxiety. (*Van*)

> When I was younger, I used to like the oral examination because I was very spontaneous and I liked to show off as a kid, but then in the university, I got to be a little bit shy to get together with people who are real mathematicians. I wasn't very good at oral examination. I was very shy and if I'm put now to grade people by oral examination that will be really hard for me especially if I have all the other people watching. (*Elisabeth*)

Melissa and Nora exemplified the second point related to being difficult to agree with which type of an exam can cause more or less anxiety in students:

> There was anxiety during the exams definitely, but whether it was more on written or oral, well [...] on average it was probably more anxiety but not significantly because there were students who preferred oral examinations, they felt that they could demonstrate their knowledge better, but overall my experiences from oral exams were positive. (*Melissa*)

> It depends on the type of personality I would say. I cannot generalize here. But from what I have seen around me, oral exam has its own anxiety, written exam has its own anxiety. In the written exam, the anxiety is that you can get something which you completely don't know. You studied everything and you didn't study this much, right? And you get exactly the questions, which are related to those two chapters, which you missed. What can you do? Nothing. Right? When there is an oral exam, there is anxiety because you talk eye to eye [...] in my country, it was normal. (*Nora*)

Even though there might be a general assumption that the level of anxiety in oral exams is higher than in written exams, not all participants agreed on that. When Nora was asked about her experience with students taking the written exams, she responded:

> I have seen young men, not girls, young men who were sitting and shaking like that in the written exam [...] we had seven hundred students in the gym writing.

> I thought one girl would need to go to the emergency. One very good student was literally losing her mind because there were so many people sitting around her, in completely unfamiliar setting in the gym where she has never been before [...] she couldn't perform. She got her much lower grade than she was actually able to get if there was a chance to talk.

5.4.4 Assessing Knowledge and Understanding

All five participants, Elisabeth, James, Melissa, Nora and Van, who had been previously exposed to oral assessment in mathematics, agreed that written exams can mostly assess procedural knowledge and instrumental understanding while oral exams can better assess conceptual knowledge and relational understanding. Each of these five participants exemplified this when they talked about their experiences with assessment practices during their teaching of undergraduate mathematics courses. Van and James explained nicely the difference between the types of questions given in oral and written exams in mathematics based on their teaching experience:

> The oral exam was more of about theoretical questions, to prove or disprove something or give me example or counter example or justify this or justify that or make a difference between this subject and this subject, more in-depth. And, the written exam was with the type of question, if this is given and this is given, then find this or find that. I often doubt if the written exam gives the complete picture. The oral exam can give an opportunity to students to show their knowledge better than the written exam. I would say that during oral examination, it is easier to discover the level of your understanding. (*Van*)

> In homework written assignments I would say more procedural, procedural in the sense of computational. In oral exams, conceptual in the sense of abstract arguments, more oriented towards prove this and that statement. (*James*)

Nora felt that conceptual questions in mathematics can only be assessed orally and when asked for an example, she responded:

> Explain to me what is derivative [...] Can you put this question on the written exam? No, because nobody has the resources to mark it. It takes forever to read students' poor handwriting and to see exactly what they discussed, from which position, is it a geometrical side [...] The understanding can be assessed only in oral exam.

Similarly, Melissa, Nora and Elisabeth described the difference between the types of knowledge and understanding that can be assessed in written and oral exams in mathematics:

> I would still say that oral examination was better in assessing understanding not just the knowledge. Oral examinations were to a deeper extent probing understanding of the concept. (*Melissa*)

> If I have oral assessment even in tutorial, I can very quickly get the picture across the class, how is the class doing. The drill part, the technical part, they can always pick up if they understood the concept. When there is an oral exam, there is an ability to show your logical thinking [...] the questions where I need to see if they understand the chain rule, the person has to explain to me in two words. They don't need to solve the problem on twenty lines. (*Nora*)

> I guess in written maybe you can assess procedure. You can see if they could follow a strategy for solving an equation. But I guess relation, it's more [...] you can do that I guess better with oral. (*Elisabeth*)

An interesting comment came from James who believed that the oral exams should be given only to mathematics major students to assess their conceptual knowledge of mathematics, while the written exams should be given to non-mathematics major students to assess their procedural knowledge:

> I think actually the ideal would almost be a mix so that I would have a short period or would give the student questions, give them ten minutes to work on it and afterwards start the oral examination. And this is really more for

> those who are in mathematics as majors. I think for people who are not in mathematics as majors, the number of people who feel very uncomfortable with oral examination is so much bigger, and it does actually make sense from this perspective to conduct a written examination, also because of the fact that for those people it's usually the case that they need more the recipe mathematics rather than the conceptual mathematics.

On the other hand, the other two participants, Dave and Jane, who had never been previously exposed to oral assessment in mathematics prior coming to Germany, believed that the written exam alone can efficiently assess both procedural and conceptual knowledge and instrumental and relational understanding. Dave believed that because of the time constraints in the oral exams, it might be a challenge to find the most suitable exam questions:

> For mathematics, the questions that can be answered quickly for me are mostly the sort of procedural questions [...] you need to think for a while to answer those questions and so I'm not sure in a context of an oral exam where you don't have very long time whether there are such good questions.

Jane also felt that conceptual questions, theory, and proofs can be better assessed in writing than orally and when asked for an example of a question that cannot be assessed orally, she responded:

> The ones that take more time to think about. Yeah [...] the time is a pretty big issue because you're doing advanced mathematics. You tend to need just more time to think about things.

The participants' beliefs on what can be assessed in oral and written exams in mathematics are presented in Table 5.3.

The participants considered mathematical problems that would better assess procedural knowledge and instrumental understanding to be computational types of questions, which would require students to perform some calculations in order to solve for an answer. On the other hand, when it comes to mathematical problems that would better assess conceptual

Participant	Written		Oral	
	Procedural / Instrumental	Conceptual / Relational	Procedural / Instrumental	Conceptual / Relational
Dave	✓	✓		
Elisabeth	✓			✓
James	✓			✓
Jane	✓	✓		
Melissa	✓			✓
Nora	✓			✓
Van	✓			✓

Table 5.3: Written and Oral Exams: What Are We Assessing?

knowledge and relational understanding, the participants considered theoretical types of questions in the sense of abstract arguments that would involve proving, justifying and defining given statements.

Another interesting finding is that for Jane and Dave time played an important role in terms of choosing the most appropriate mathematical questions for the exam. Moreover, it was interesting to see that both Jane and Dave were relating "conceptual" types of questions in mathematics to the questions that would take more time to think about, and so, they can be only answered through the written exams. Oppositely, they considered the questions that can be answered quickly to be sort of "procedural" questions, and only these types of questions can be assessed orally. On the other hand, the other five participants thought completely opposite to these two, so that conceptual mathematics questions can only be assessed through the oral exams while procedural mathematics questions through the written exams.

5.5 Clusters of Espoused Beliefs and Their Relationships

The goal of this section is to identify the relationships between the participants' espoused beliefs about the nature of mathematics, mathematics assessment, and written and oral mathematics assessment. Based on Green's (1971) concepts of *primary* and *derivative* beliefs, I looked into the espoused beliefs that have direct relation to mathematical beliefs. Moreover, with the addition of espoused beliefs about written and oral mathematics assess-

ment, I proposed the third belief system, *sub-derivative* belief - a belief that is derived from a *derivative* belief (a belief that is derived from a *primary* belief). Based on the participants' prior schooling and teaching experience in oral and written assessment cultures, I was able to identify two clusters of beliefs. These clusters of beliefs are presented in Figure 5.1a and Figure 5.1b. Throughout this thesis, I will be referring the oral assessment cultures restricted to countries that are involved in this study, and these are: Bosnia, Germany, Poland, Romania, and Ukraine. Also, I will be referring the written assessment cultures as countries of Canada and the United States.

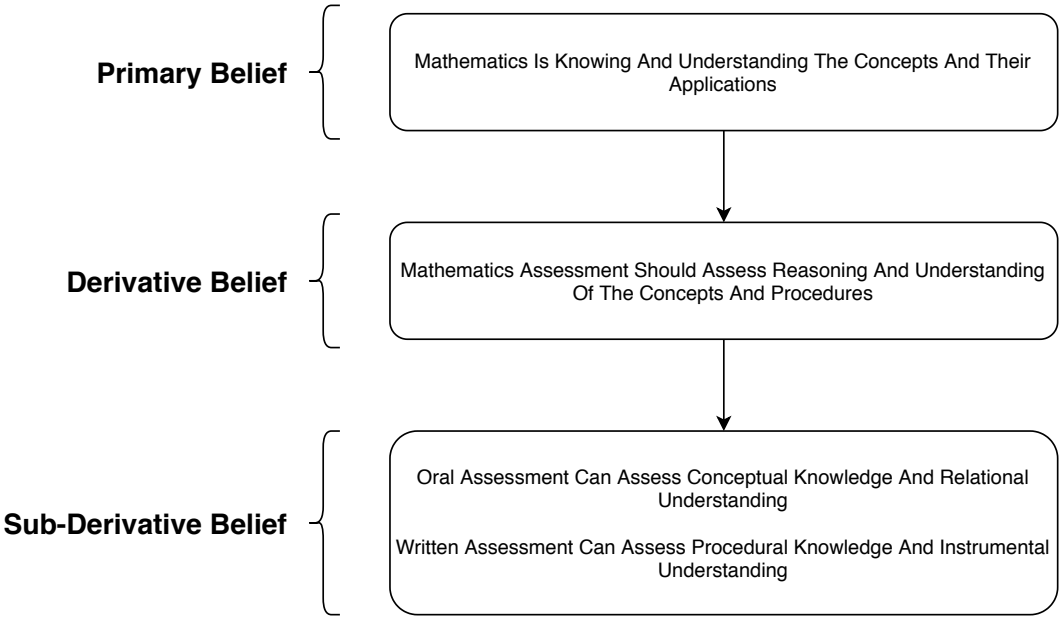

Figure 5.1a: Cluster of Espoused Beliefs Based on the Participants' Schooling and Teaching Experience in Oral Assessment Cultures

Figure 5.1a and Figure 5.1b represent both clusters with a primary belief 'mathematics is knowing and understanding the concepts and their applications' and a derivative belief 'mathematics assessment should assess reasoning and understanding of the concepts and procedures'. These primary and derivative beliefs are explained in Table 5.1a and Table 5.1b. On the other hand, both sub-derivative beliefs, 'oral assessment can assess conceptual knowledge and relational understanding, and written assessment can assess procedural knowledge and instrumental understanding' (Figure 5.1a), and 'written assessment can assess conceptual knowledge and relational understanding, and procedural knowledge and instrumental

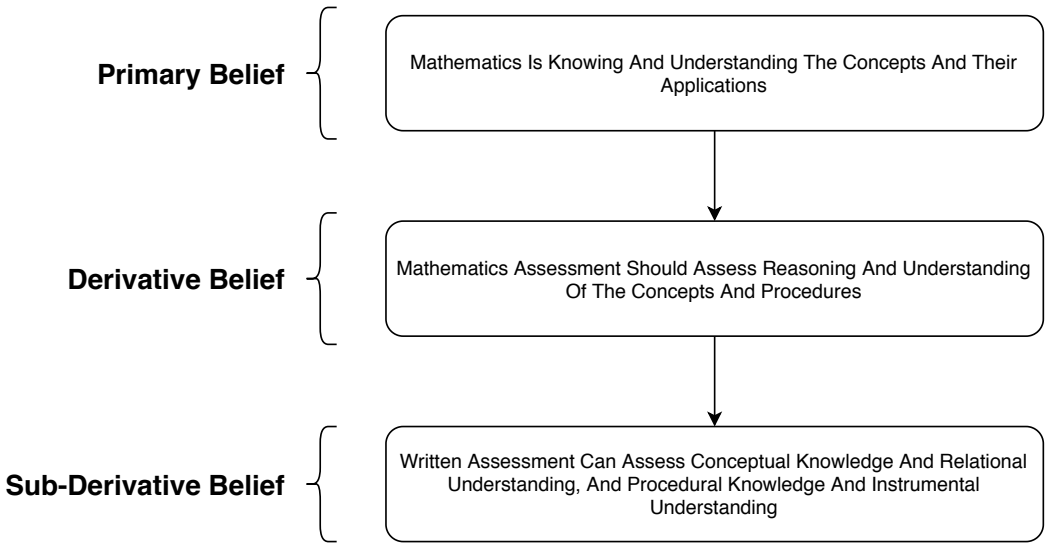

Figure 5.1b: Cluster of Espoused Beliefs Based on the Participants' Schooling and Teaching Experience in Written Assessment Cultures

understanding' (Figure 5.1b), are derived from a derivative belief. These sub-derivative beliefs are explained in Table 5.3, and they are based on the participants' prior (or lack of) exposure to oral assessment in mathematics.

5.6 Constraints and Opportunities of the Teaching Context and the Socio-Cultural Norms

The data show that the participants' practices of teaching and mathematics assessment are influenced by the social and the cultural contexts of the teaching situation, in other words, the socio-cultural norms (Yackel and Cobb, 1996). These normative expectancies are considered as institutional and socio-cultural shared beliefs within the classroom setting, and they define both the teachers' and the students' roles.

One of the many differences between attending university in oral and written assessment cultures is that, in oral assessment cultures, students are expected to attend university free of cost. Elisabeth and Nora exemplified this when they talked about their own university experience as being a student in Romania and Ukraine:

> After graduating from university, we were sent to work because we did not pay tuition. We needed to do some return of service. (*Elisabeth*)

> Basically, in Ukraine, we were all paid scholarships. (*Nora*)

Moreover, most of the students were not expected to work during their undergraduate studies in comparison with students who are attending universities in Canada or the United States. Melissa commented on her undergraduate experience in Poland:

> People seldom worked to support themselves because they usually had their parents supporting them or they had government grant and tuition was free which again contributed to less need for work [...] but here in Canada these days we have large percentage of students who work, or they have family. When I was a student, it was unthinkable that you'd have a family while undergraduate student.

Another difference between attending university in oral and written assessment cultures is that in oral assessment cultures students are expected to declare their undergraduate major of study right upon their university admission. This would not be the case for the students who are attending universities in Canada or the United States where most of the students would not have to declare their major of study in the first two years of their undergraduate studies. James and Jane explained this difference between studying in Germany and the United States:

> In the bachelor system in Germany you already start out with a major. (*James*)

> I did end up changing my major. I actually started mechanical engineering. Certainly, I knew plenty of people in the U.S. who had no idea what they wanted to do, didn't have a major for a while or changed their majors a number of times. Whereas, in Germany you kind of come in, and if you're a math major, then you start out your math major and you will take math classes. (*Jane*)

Also, there was an interesting comment made by Jane when she compared the undergraduate students who are studying in Germany versus in the United States:

> I haven't had any German students complain about grades yet. In the U.S., students like to complain about their grades. Yeah, I feel like there is kind of some sense of entitlement especially in the U.S. from the students.

Now, when it comes to the participants' teaching in oral and written assessment cultures, the participants who are teaching in written assessment culture are expected by their institution to more frequently evaluate their students, but also expected to be regularly evaluated by their students. Nora explained this based on her teaching in Canada:

> There is unfortunately a situation when some of the classes are taught by sessional instructors, and sessional instructors depend on evaluation from the students. How do you get good evaluations? If students get good grades. How do you get good grades? The easy way is to give easy mid-terms.

On the other hand, the participants who are teaching in Germany are not expected to be regularly evaluated by their students during their teaching. Jane explained this difference between teaching in the United States and Germany:

> In the U.S., in every single course that you have, at the end of the course there is an anonymous written evaluation. The department collects them all and then you see all of them and numbers [...] that's not how is in Germany, for most classes you do not get evaluations.

Furthermore, the participants who were educated in oral assessment cultures, they believe that the responsibility for the student's learning should be solely placed on the student himself/herself. James' response exemplified this:

> I mean I don't really have the idea that after a lecture everybody understood what I did on that lecture. But, it's rather that if they would take the time to think about what I said while reading what I wrote and while doing the homework, they will put the puzzle together themselves.

On the other hand, the participants who were educated in written assessment cultures, they believe that the professor and the student are both responsible for the student's learning. Dave's response exemplified his personal beliefs on learning and teaching mathematics:

> I suppose my answer to that is that if they haven't learned it, it's not necessarily their fault. I'm also meant to be teaching them something. And if nobody has learned it, it probably means that I'm not teaching it very well. And then that's the reflection on me. So, yeah, my assessment is assessing me as well and so then I need to think about how I could be doing this better.

The participants who are teaching mathematics in written assessment cultures face many restrictions within their teaching institution and mathematics department. These participants are just simply asked to follow the provided curriculum and textbook for the mathematics courses that they are teaching. Dave exemplified his teaching experience in Canada:

> I was given the curriculum, I was told to teach them this, I tried to and then I assessed whether or not they have learned it by giving exams that were similar to the exams that people have given in the past years.

Also, Jane explained her similar experience while teaching in the United States:

> In the U.S. system, in my experience, specifically with the large state schools, and this might be different if you're in a small liberal arts college, but there are so many different rules and regulations. For example, when you have a course even if it is a more advanced course, and you're the only one who is teaching it, you're still required to put out a syllabus that has a very specific things you will be covering and on which days.

However, the participants who are teaching mathematics in oral assessment cultures, they have more freedom within their teaching practice of mathematics and assessment. Dave, James and Jane exemplified their teaching experience in Germany:

> Everybody is doing pretty much what they want. I can pretty much decide. (*Dave*)

> It is really a decision of myself. So, I can say, okay, I mean for fifty students I don't really want to go through the procedure of oral exams, I just choose to have written exams, or I could say, well, for these thirty people now I really want to get to know them, so I will do oral exams. (*James*)

> In Germany an instructor has a lot more freedom. I decide exactly what it is contained in the course. So, it is very different. If I was teaching the similar kind of course in the U.S., I would not have as much freedom of what I was covering in the course. (*Jane*)

These participants' responses determine the following social expectations that exist within the oral and written assessment cultures:

- *Within the oral assessment culture, students are expected:*
  - to attend university of no or minimum cost;
  - to declare their undergraduate major of the study right upon their university admission;
  - to take written and oral exams in their mathematics courses;
  - less frequently to be assessed in their mathematics courses;
  - less likely to have jobs.
- *Within the oral assessment culture, mathematics professors are expected:*
  - less frequently to be evaluated;
  - to experience greater autonomy to choose what to teach and how to assess in their mathematics courses.
- *Within the written assessment culture, students are expected:*
  - to pay full cost of university tuition and fees;

  - to declare their undergraduate major of the study after two years of attending university;
  - to take only written exams in their mathematics courses;
  - more frequently to be assessed in their mathematics courses;
  - more likely to have jobs;
  - to have some sort of sense of entitlement.

- *Within the written assessment culture, mathematics professors are expected:*
  - more frequently to be evaluated;
  - to experience many restrictions within their teaching institution and mathematics department, such as: the institutionalized curriculum (the adopted text or curricular scheme), the system of assessment, and the overall national system of schooling.

Based on these socio-cultural norms that exist within the learning and teaching contexts, the participants' beliefs show clear division between studying and teaching in oral assessment cultures and written assessment cultures in terms of constraints and opportunities within each of these two cultures. The results show that the participants who are coming from oral assessment cultures and currently are teaching mathematics in a written assessment culture have to face many constraints within their assessment practices and teaching of mathematics that are not necessary aligned with their own personal beliefs. These constraints are: issue of time to administer oral exams; students' expectations and behaviors; institutional and mathematics department beliefs; school cost; professors' teaching evaluations; the adopted mathematics curriculum and mathematics textbooks. On the other hand, the participants who are coming from written assessment cultures and currently are teaching mathematics in oral assessment culture are given the opportunity to teach and assess mathematics within the alignment of their own personal beliefs.

The participants' responses indicate that the espoused and enacted models of mathematics assessment are to be viewed as separate entities that do not fall under learning or

teaching model particularly (see Figure 4.1). Based on the data, the espoused and enacted models of mathematics assessment can fall under either, learning model or both, learning and teaching models, depending on the culture that we are looking into.

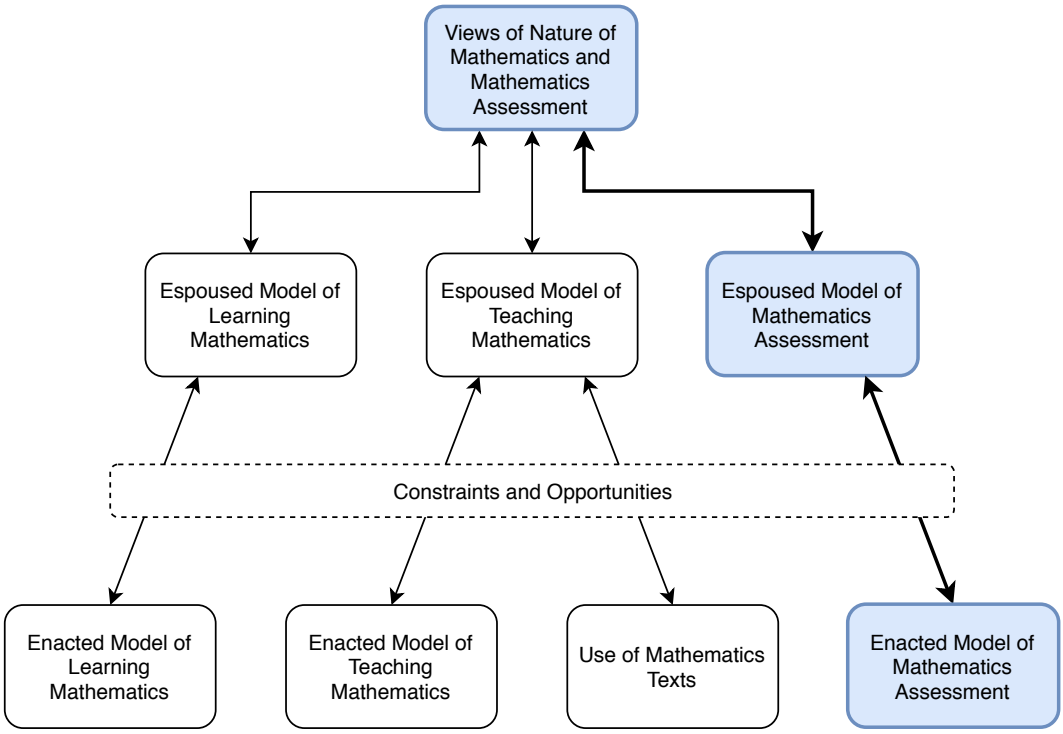

Figure 4.1: Modified Version of Figure 3.1: Relationships Between Beliefs, and Their Impact on Practice

In written assessment cultures, the espoused and enacted models of mathematics assessment are part of the models of teaching and learning mathematics. The importance is placed on both, assessing teachers' teaching and assessing students' learning. Based on the socio-cultural norms in written assessment cultures, mathematics professors are expected more frequently to be evaluated by their students and to experience many constraints within their teaching institution and mathematics department, such as the institutionalized curriculum (the adopted text or curricular scheme), the overall national system of schooling, etc. The responsibility for the student's learning is shared between the teacher and the student.

In oral assessment cultures, on the other hand, the espoused and enacted models of mathematics assessment are part of the model of learning mathematics, with a great emphasis on assessing students' learning. Based on the socio-cultural norms in oral assessment

cultures, mathematics professors are less frequently evaluated by their students and experience greater autonomy to choose what and how to teach. The greater responsibility for the student's learning is placed on the student himself/herself.

Thus, when participants were asked to share their personal views on mathematics assessment, the only participants who mentioned in their interviews that the responsibility should be shared between the teacher and the student were Dave and Jane, both educated in written assessment cultures. The other five participants focused solely on students' responsibilities for their learning and grades.

5.7 Enacted Mathematics Assessment Practice

The participants' past and present enacted mathematics assessment practices are presented in Table 5.4.

Participant	**Past**		**Present**	
	Oral	**Written**	**Oral**	**Written**
Dave		✓		✓
Elisabeth	✓	✓		✓
James	✓		✓	✓
Jane		✓		✓
Melissa	✓	✓		✓
Nora	✓	✓		✓
Van	✓	✓		✓

Table 5.4: Past and Present Enacted Mathematics Assessment Practices

Those participants who were exposed to oral assessment in the past, their past enacted mathematics assessment practices consisted of both written and oral assessment. Van exemplified the typical structure of the oral examination in undergraduate mathematics courses:

> In undergraduate studies the format was always the same. You would come to examination room, the instructor would put maybe a dozen maybe twenty cards with the questions and you would pick one without knowing what is on that card, and you would be given fifteen, twenty minutes to prepare to answer those questions and you would go in front of usually other students and the

> professor and often teaching assistant. And, you would start doing whatever was on that card. Usually, you would be asked to state a proof or theorem or to give an example or counter example for something. So, the questions were challenging.

Furthermore, the participants who were exposed to oral assessment in the past, their current enacted mathematics assessment practices are written assessment only. Elisabeth exemplified this when she talked about her current enacted assessment practices in one of her undergraduate mathematics courses that she teaches in Canada:

> We have ten written quizzes, ten homework assignments, many online quizzes. Every week there is online quiz and two mid-terms and the final exam. So, in the end, the final grade is out of thirty, thirty-four grades.

The amount of written assessment in undergraduate mathematics courses in Germany is much less than in Canada. Dave and Jane shared their experiences with mathematics assessment teaching in Germany

> Two hours written examination at the end and some homework assignments for the workshops, but those are just sort of pass/fail evaluated. So, the only assessment that counts is the examination. (*Dave*)

> There are no quizzes and there are no mid-terms [...] the first exam is written and then, if the student fails that exam, the following semester they have a chance to take an oral exam. And then, if they failed that exam, then they have a chance to take the written exam when it is offered again as part of the class because the course is offered every winter semester. Personally, I am still kind of against oral examinations. So, yeah, I kind of gave the students my reasons for thinking that it would be better to have a written exam. And I said that they could choose. And, actually they chose written exam, but there was one student, he was actually the best student in the class by far and because it wasn't an oral exam, he just decided not to take the exam. (*Jane*)

Due to constraints and opportunities within the oral and written assessment cultures, some participants had to change their enacted assessment practices in their teaching of mathematics, that do not correspond to their espoused beliefs about mathematics assessment. Thus, a new diagram is created, which illustrates the relationship between the participants' espoused beliefs about mathematics and mathematics assessment, and their impact on enacted mathematics assessment practice within the oral and written assessment cultures (see Figure 5.2).

This diagram shows how the participants' espoused beliefs about mathematics assessment, which are based on their prior schooling and teaching experience, school culture, and study program within the assessment culture, are transformed into their classroom, which represents the enacted mathematics assessment practice. The espoused beliefs about mathematics assessment, written and oral, are subject to constraints and opportunities of the teaching context which are influenced by the socio-cultural norms that exist in oral and written assessment cultures.

Therefore, Van, Melissa, Nora, and Elisabeth, who had been previously exposed to oral examination in mathematics before moving to Canada, in other words, who came from oral assessment cultures to a written assessment culture, are currently facing many constraints within their assessment practice and teaching of mathematics. Their espoused beliefs about mathematics assessment as being subject to the constraints of the teaching context within the written assessment culture are transformed into their assessment practice, which represents enacted mathematics assessment practice. Thus, these participants' current enacted mathematics assessment practices are not consistent with their espoused beliefs about mathematics assessment. On the other hand, Dave and Jane, who came from written assessment culture to oral assessment culture, are currently experiencing in Germany many opportunities within their assessment practice and teaching of mathematics. In addition, James who was born, educated, and currently teaching in Germany is also experiencing many opportunities within his assessment practice and teaching of mathematics. Their espoused beliefs about mathematics assessment as being subject to the opportunities of the teaching context within the oral assessment culture are transformed into their assessment practice, in the

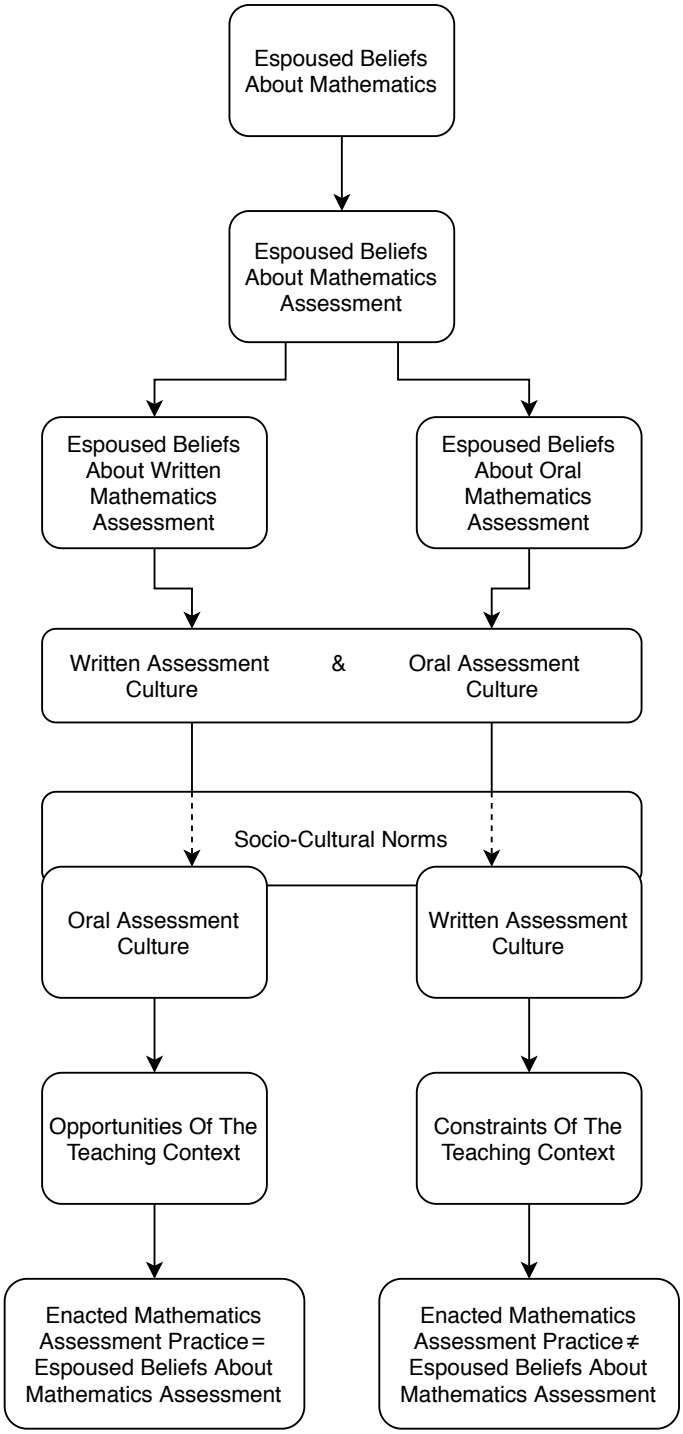

Figure 5.2: Participants' Espoused Beliefs about Mathematics and Mathematics Assessment, and Their Impact on Enacted Mathematics Assessment Practice Within the Oral and Written Assessment Cultures

way that their current enacted mathematics assessment practices are consistent with their espoused beliefs about mathematics assessment.

5.8 Concerns with Implementing and Discontinuing Oral Assessment in Mathematics

Implementing oral assessment in written assessment cultures and discontinuing oral assessment in oral assessment cultures might raise some concerns among the students and the professors at universities in oral and written assessment cultures. Based on the participants' responses, the implementation of oral assessment in written assessment cultures might raise the following concerns:

- Issue of perceived subjectivity in the oral exams;
- Issue of finding the time to administer the oral exams;
- Adopted norms in mathematics department;
- Issue of fairness in the oral exams;
- Issue of making the oral examination public for undergraduate students;
- Students need to be trained how to deliver the material orally;
- Students would feel upset (sense of entitlement).

When it comes to an issue of making the oral examination public for undergraduate students, this was referred to the students having greater anxiety if they were about to perform the oral exams publicly in front of their class peers and/or professor(s). Van commented on this:

> When I'm thinking about doing this, I'm thinking rather about weaker students giving them a chance to present themselves in a better way. And, it is difficult to say, I can tell you that I have, or I had students in my classes that would just freeze during this written examination. And you know another problem that I'm having with this idea is, can we make this public? Can we do this in this moment

of time, in this place? Can we do a public oral examination for undergraduate students?

In response to an interview question, 'If you are about to implement (or discontinue) oral assessment in your current mathematics courses, what could you predict?,' the participants expressed their concern that if oral assessment was about to get implemented in written assessment cultures, the students would certainly need to be provided with a training on how to deliver the mathematics material orally. Nora explained that in order for the students in written assessment cultures to adopt the oral exams in their mathematics classes, it would take some time for the students to accept a different method of assessment in their classes than what they are already used to:

> They need to go through the training to deliver the material that they learned. The students need to be prepared for this, and at least for the first few years until it becomes a tradition, I would give them the option. You can have only the written exam, or you can have part of the exam written and part of the exam oral. I would do that because, again, they're conditioned in high school for many years [. . .] we had oral exams from grade five every year. It was very stressful, but in some way, we were already dealing with this [...] again, it would take a while for the students to get reconditioned.

In this process of the possible students' adaptation to the oral exams, Jane commented that the students might express their resistance for this change to happen:

> I mean especially at lower level courses the students would be very, very upset. Because, you know, students like to complain about their grades, and when they have like something in hand, they can say I wrote this, but you said this, and I think I deserve more points. But if that's not possible, if it's just kind of like there are a couple of little notes that someone wrote down on an oral exam and the professor says you get a particular grade [...] yeah, I feel like there is kind of some sense of entitlement, especially in the U.S. from the students, and I think that would not go very well.

On the other hand, the discontinuation of oral assessment in oral assessment cultures might raise the following concerns:

- Professors and students would feel uncomfortable;
- Issue of lacking a freedom of teaching;
- Issue of getting to know mathematics students better.

If oral assessment was about to get discontinued in oral assessment cultures, the professors and the students would certainly not feel comfortable with this change. Dave and Jane explained that this switch would cause some professors and students to feel uncomfortable because they are already used to doing things a certain way:

> I think people are already feeling or some people are feeling that they are now too much written going on, and so people would be unhappy about it. Germans are generally, and this is sometimes a character flaw and sometimes a very good thing, but they're generally very law-abiding people. So, if somebody decides that everybody is going to do something, then usually they just go ahead and do it. They're not likely to rise up and rebellion. They will grumble and complain but they will do it. (*Dave*)

> I think it would be negative, but part of that is that people are used to doing things a certain way, and it is hard to change. For example, the math department still has chalk boards, and you know, so many other departments have moved on to white boards or whatever, but in math department there are chalk boards. Mathematicians especially don't like to change the way they do things. (*Jane*)

Another reason why some professors would feel opposed to this change is that this change would make them feel that their right to teach their classes freely is taken away. James explained this:

> When it comes to math majors, I think the concern or immediate consequence of what I said earlier about the value of oral examination that this would disallow

us as professors to get to know the students on a level that is appropriate for further masters or higher-level studies. So, it would just directly work against what we want to do with our math students or with the advanced students, and that I think is a very valid concern. Also, it's just a concern that this is an immediate, I mean that the state would just violate our independence as professors to freely do study and research somehow. In Germany, this is always going together as a concept, so it's the freedom of teaching and doing research. And, I think that would legally actually be impossible.

The participants' responses show that there are some common concerns shared between the current constraints that exist within the enacted mathematics assessment practice and teaching of mathematics in written assessment cultures and possible future concerns that might arise with implementing oral assessment in written assessment cultures (see Figure 5.3).

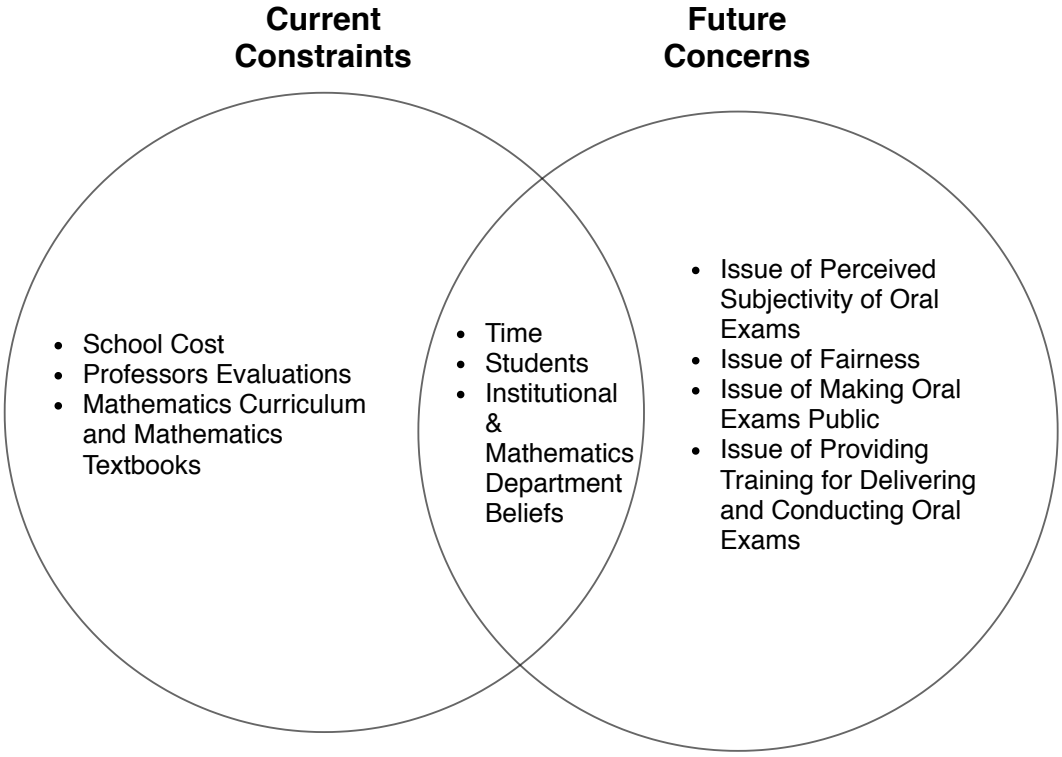

Figure 5.3: Current and Future Common Concerns with Implementing Oral Assessment in Written Assessment Cultures

When it comes to implementing oral assessment in written assessment cultures, both current and future concerns are: the issue of finding the time to administer the oral exams, the issue of having students adjust to new assessment practices, and the issue of changing the accepted norms and the espoused beliefs about mathematics assessment within the teaching institution and mathematics department.

On the other hand, there are no common concerns shared between the current opportunities that exist within the enacted mathematics assessment practice and teaching of mathematics in oral assessment cultures and possible future concerns that might arise with discontinuing oral assessment in oral assessment cultures (see Figure 5.4).

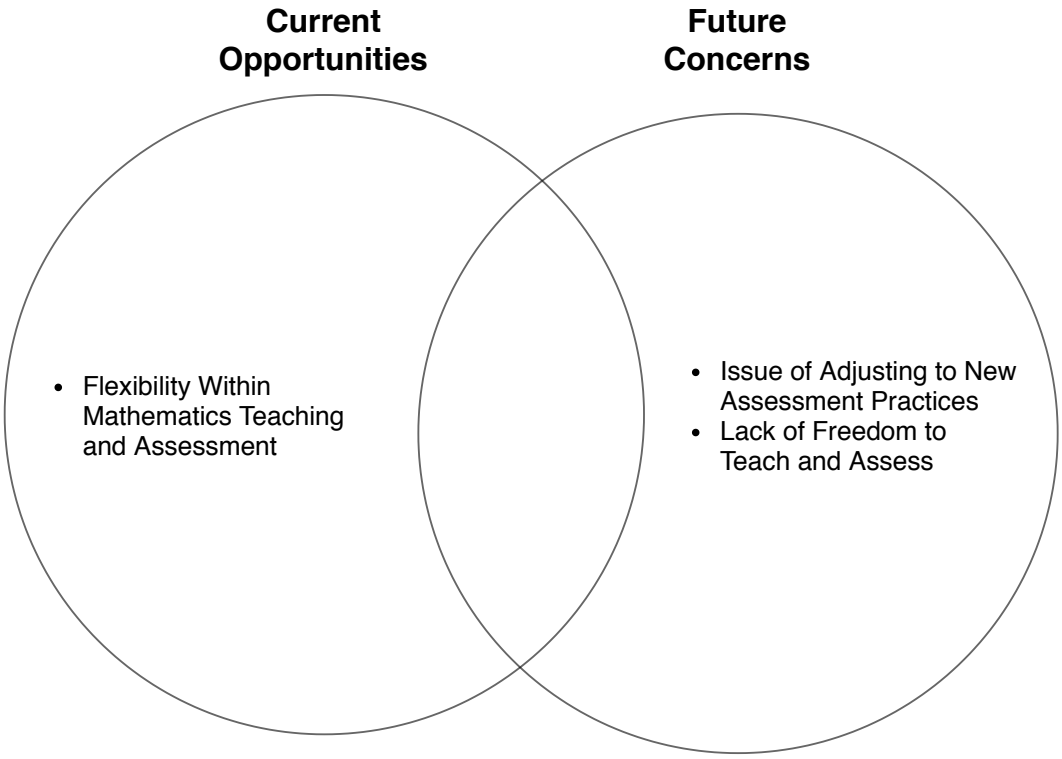

Figure 5.4: Current and Future Common Concerns with Discontinuing Oral Assessment in Oral Assessment Cultures

When it comes to discontinuing oral assessment in oral assessment cultures, as there are no current constraints that exist within oral assessment cultures, only future concerns might arise, such as: the issue of having students and professors adjust to new assessment

practices and the issue of experiencing the lack of freedom within the assessment practices and teaching of mathematics.

As a result of both, the common concern between implementing oral assessment in written assessment cultures and discontinuing oral assessment in oral assessment cultures is certainly the issue of having students and professors adjust to new assessment practices.

It was already discussed that the participants' espoused beliefs about mathematics assessment are based on their prior schooling and teaching experience. The prior experiences tend to make most of the people to have a hard time adapting to any change, a positive or a negative one. Dave explained this when he commented on possible future concerns that might arise with implementing oral assessment in written assessment cultures:

> I think that you'd see a lot of variation. There would be some professors who would say, "Yeah finally," and some students who would say, "Yeah, this makes sense. I always hated written examinations. I look forward to having an alternative." And you would have some people who would say, "I've never done this. Nobody I know has ever done this. Why should we change?" A parallel might be at university where I was teaching in Nova Scotia just before I started there, so this would now be of 20 years ago. The president of the university said, "We're going to become a laptop university. Every student is going to have a laptop, a computer with them in their classrooms, every teacher is going to use the computers in their teaching." And some people said, "Yes, finally I can do interesting things with technology" and other people said, "Come on, I'm a mathematics professor. Mathematics professors have been teaching mathematics using chalk and chalk boards for 500 years and why on earth should I change."

On the other hand, just because sometimes we get used to doing things in a certain way, this does not necessary mean that we always agree with it. Van commented on his prior schooling and teaching experience in Bosnia:

> It was a different time. Nobody paid any attention about my privacy rights or you know exposing me to be stupid in class. An example that comes up to

> my mind is back when I was a student, and when I was teaching back home. Having a student with a disability was really something that I cannot recall, any experience, having a colleague having a fellow student in a class with learning disability or having a student in my class with learning disability. That was really kind of brushed away. I can tell you that here at (*university where he currently teaches*) I had a few students with a disability who were the best students I have ever had, the smartest, the kindest, and the most successful people that I can think of. And, that makes me think that the system in place is really to help people.

In terms of implementing oral assessment in written assessment cultures, the need for the students as well as for the professors to be trained how to deliver the material orally and to successfully conduct the oral assessment in mathematics classes came up as an important concern. Moreover, the data show that the examiner should have certain skills in order to be able to administer the oral assessment successfully.

The participants who were educated in written assessment cultures believe that having the intuition is a crucial skill for conducting the oral assessment, and this intuition needs to come from the cultural background of someone who had already been exposed to the oral assessment in his/her previous schooling or teaching. Dave exemplified this:

> Somebody who is coming out of twenty years of experience of being asked questions in the oral examinations has a different experience than somebody who is just starting to do this as a professor at the university. And that would be for in the Canadian context too. Something that would be very tricky to negotiate that there would be students who had never done oral examinations who would not really know how one is supposed to behave. So even if you had professors who would come from Europe, doing the oral examinations, they would be doing them with students who didn't have the same background, culture in them. Asking Canadian professors who hadn't come from backgrounds where oral exams were used to start doing this, you'd have a whole bunch of people

> who maybe you could teach them the knowledge that they needed to know but they wouldn't have the intuitions that they would need to do this well.

Oppositely, the participants who were educated in oral assessment cultures believe that everyone already has the skill within himself/herself, so it is just a matter of practicing it. James explained this:

> I could imagine that this is something like a soft skill that many people just carry in them, and then it is just a matter of practicing it and gaining some experience.

When it comes to grading exams, there are some differences between how the oral and the written exams are graded. These differences are pertaining to: grading time, grading efficiency, grading rubric, and how the grades are assigned on the written and the oral exams. In terms of grading time and efficiency, the participants' responses indicate that grading the oral exams takes less time and is more efficient than grading the written exams. Elisabeth and Dave exemplified their experiences with grading the oral and the written exams when it comes to grading time and efficiency:

> When grading the oral exams, some professors they were just discussing and looking a little bit at your work and could decide on the spot. So, you had to go in and when you go in, we used to have a book, a student book where they could record the grade. Stepping out, you'll have the grade in the book and on professor's list. The professor had a list with names, so the mark would be in two places, in my personal grade book and in professor's. (*Elisabeth*)

> In terms of assessment as a feedback for the students, they need to get that feedback fairly quickly. My experience in Canada was that it takes a while for somebody to mark all of those assignments, and it takes a while for them to come back. And by that time, I don't know if the students really looked at what they got right and what they didn't get right and used it as a feedback mechanism. (*Dave*)

In terms of grading rubric, the participants who have experience with oral exams in their mathematics courses claimed that they never used any rubrics for grading the oral exams. Van explained this:

> Later in my professional life I was in a position to do some exams on my own and to be part of this process. But, I don't remember that anybody was using rubrics. I mean I believe that most of this was really based on the experience and on the impression. And, I remember when I was teaching assistant with this particular professor, if there were some kind of dilemma or doubt, he would quickly go with me, so 'what do you think of this and this,' but I believe that they run really on their experience and their assessment of performance that was in front of them.

On the other hand, when it comes to grading the written exams, grading rubric was almost always used. Jane commented:

> So, before I start grading, I write a full rubric. I often have in written exam all point values assigned in different sub parts. But, then I often find for example, there'll be a certain kind of error that a student will make and usually students tend to make similar errors. So, a lot of times then I kind of I have my base rubric and then I'll say, okay, if they make this type of mistake, then I take off this amount of points and then I'll write that down. And so, the next time I see a student who has made the same mistake then I give him/her the same amount of points.

Lastly, when it comes to how the grades are assigned on the oral and the written exams, in other words, how the grades are assigned in oral vs written assessment cultures, the difference is that in oral assessment cultures the grades are presented as digits while in written assessment cultures the grades are presented as letters. Nora explained this difference based on her teaching experience in Ukraine and Canada:

> We had a very much simplified grading system compared with the local one. Again, it's debatable, is it good or bad. But, we had basically the grades: 5, 4,

> 3 and 2. 5 was, which would be here, A+. That had to be perfect. No glitches. You had to be able really to reply to all questions which you picked up and all additional questions. Yes, you could get some guidance, but you had to really know your stuff. [...] and if you cannot answer major questions, 2 is a fail. If you got a 2 within the same semester, you were given a chance within 2-week period to retake the exam. It would still be noted on your transcript, but you could retake it and the better grade would be counted toward the outcome.

Furthermore, for those professors who were educated in written assessment culture, and they are currently teaching in the same written assessment culture, but are willing to try to implement oral assessment in their teaching and assessment practices, the following didactical recommendations are suggested:

- define the aim of assessment (for example: to assess knowledge and understanding or problem-solving ability, or personal qualities);
- define the interaction of assessment (for example: presentation - where no questioning or discussion is allowed or interrogation - as interactive dialogue, or combined);
- define the context of assessment (for example: assessment conducted in the classroom or outside of the classroom - assessment conducted online using Zoom);
- define the structure of assessment (for example: closed - little interaction between student and examiner or open - opportunity for dialogue between student and examiner);
- define the examiner (for example: self-assessment, peer-assessment, or authority-based assessment);
- define the orality (for example: assessment is purely oral by word-of-mouth or combined with other media such as a written paper or using school board);
- create rubric and criteria for grading;
- examiner should take the notes during exam (notes can be used for marking and in providing feedback to the student);

- if more than one examiner is involved, one of them can record student's responses while the other does the questioning;
- exam could be audio or video recorded (to keep it as a record in case a student wants to review his/her grade);
- students should be provided with some examples of oral assessment (either live or on video);
- students should have an opportunity to practice oral assessment (for example: students could practice oral assessment during the tutorial hours with their teaching assistants);
- professors who already have experience with oral assessment could provide some professional training to their colleagues and teaching assistants;
- oral assessment could replace one of the formative assessments (for example: to replace a quiz or weekly homework assignment);
- students may be given an opportunity to choose between oral or written exam.

Chapter 6

Conclusions

Initially, I began this research because I wanted to find out how mathematics professors experience and view oral and written assessment in mathematics, and I was hoping to find out many research studies that address mathematics professors' beliefs about assessment in mathematics. But, when I started reviewing the literature on mathematics assessment, I discovered the lack of research on oral assessment in mathematics classroom. On the other hand, I noticed a large amount of research on teachers' beliefs about mathematics, mathematics teaching and mathematics learning. In this research, I discovered that the primary espoused belief about mathematics was that 'mathematics is knowing and understanding the concepts and their applications'. This is consistent with the research that showed that beliefs about mathematics play a key role on the teachers' mathematical beliefs (Beswick, 2007; Cross, 2009; Liljedahl, 2009). In particular, the results of this thesis showed that similar beliefs about mathematics result in different beliefs about mathematics assessment.

In the remainder of this chapter, I summarize the main research findings, identify the contributions that this study makes to the area of mathematics assessment, discuss the limitations of this study, the recommendations for possible future research, and some final words.

6.1 Answering the Research Questions of the Study

In the analysis presented in Chapter 5, all three research questions of this study, "*What are the mathematics professors' views on written assessment in mathematics?*", "*What are the mathematics professors' views on oral assessment in mathematics?*", and "*What are the*

mathematics professors' views on their mathematics assessment practice?", have already been addressed. In what follows, I recap the responses to all three research questions and present my response to the main research question of this thesis, "*What factors influence mathematics professors' views on oral assessment in mathematics?*"

The primary espoused belief about mathematics ('mathematics is knowing and understanding the concepts and their applications') was also included in the participants' espoused beliefs about mathematics assessment. In other words, the participants' espoused belief about the purpose of mathematics assessment was derived from their primary espoused belief about mathematics - 'mathematics assessment should assess reasoning and understanding of the concepts and procedures'. This belief about the purpose of mathematics assessment is closely related to one of the three major purposes of assessment according to Brown (2008), which is that the purpose of assessment is to improve teaching and learning. In this 'assessment as improvement of teaching and learning', the purpose for assessing students' knowledge and understanding is to gather information that would lead to changes in teaching and learning practices, so that improvement in student's achievement can be facilitated. The other two purposes of assessment highlighted by Brown, 'assessment as making schools and teachers accountable for their effectiveness' and 'assessment as making students accountable for their learning', are also connected to the results of this thesis, based on the participants' teaching cultures. So, when it comes to assessment as making schools and teachers accountable for their effectiveness, which focuses on demonstrating the quality of teaching and learning, this was more present in the participants' teaching in written assessment cultures, due to their frequent students' evaluations. On the other hand, student accountability assessment that has a goal to hold students individually accountable for their learning, grades, and whether they have met various curriculum objectives, was more dominated in the participants' teaching in oral assessment cultures, due to their less frequent students' evaluations.

The participants' espoused beliefs about written and oral mathematics assessment were derived from their espoused belief about the purpose of mathematics assessment ('mathematics assessment should assess reasoning and understanding of the concepts and proce-

dures'), and they were strictly based on their prior exposure (or not) to oral assessment in mathematics. The participants who had been exposed to oral assessment in mathematics, their sub-derivative belief about written and oral mathematics assessment was that 'oral assessment can assess conceptual knowledge and relational understanding, and written assessment can assess procedural knowledge and instrumental understanding'. On the other hand, the participants who had not been exposed to oral assessment in mathematics, their sub-derivative belief was that 'written assessment can assess conceptual and procedural knowledge, and relational understanding and instrumental understanding'. These aspects of oral and written assessment in mathematics had not been specifically discussed in previously reviewed literature on mathematics assessment. The closest research to these results on what can be assessed in oral assessment is that oral assessment promotes deep comprehension of the learned material (Iannone and Simpson, 2012, 2015; Joughin, 2007; Lianghuo and Mei, 2007; Nelson, 2010; Nor and Shahrill, 2014; Odafe, 2006; Roecker, 2007), provides long-lasting mathematical knowledge (Iannone and Simpson, 2012), and can determine students' critical thinking abilities (Badger, 2010).

The participants' espoused beliefs about the positive aspects of oral assessment in mathematics are consistent with the research which showed that the oral assessment: is reactive to students' needs (Iannone and Simpson, 2015), allows for probing knowledge through dialogue (Badger, 2010; Joughin, 1998; Odafe, 2006), provides immediate feedback (Boedigheimer et al., 2015; Iannone and Simpson, 2012; Odafe, 2006; Roecker, 2007), prevents plagiarism (Huxham et al., 2012; Joughin, 1998; Nor and Shahrill, 2014), encourages students to deeply engage with the course material (Boedigheimer et al., 2015; Iannone and Simpson, 2012; Nor and Shahrill, 2014; Odafe, 2006), and prevents one small gap in knowledge completely stalling a solution (Joughin, 1998), or, in other words, provides an opportunity to adapt the level of questions to each student's level of response. The participants also mentioned that the oral assessment provides an opportunity for students to assess themselves by listening to their classmates during the oral examination. This aspect of oral assessment had not been introduced in any of the literature on oral assessment discussed in Chapter 2.

When it comes to the participants' espoused beliefs about the negative aspects of oral assessment in mathematics, the data showed that 'beliefs that are held without regard of evidence, or opposite to evidence, or apart from good reasons' (Green, 1971) can influence the views on oral assessment in mathematics. These non-evidential beliefs were pertaining to the participants' beliefs about fairness, lack of time to conduct the oral exams, and students' anxiety in oral and written exams. The results of this thesis showed that it is not quite clear which type of an exam, oral or written, is to be considered more fair or could make students feel more anxious during the time of examination. These results are consistent with the previously discussed research on disadvantages of oral assessment when it comes to the questions of fairness and anxiety (Henderson et al., 2002; Hounsell et al., 2007; Huxham et al., 2012; Joughin, 2007) in relation to unfamiliarity or lack of experience with oral assessment.

Furthermore, Nora, who was educated in Ukraine, mentioned that in her previous schooling she experienced some sort of gender discrimination by an examiner during the oral exam in mathematics. In addition, Van, Elisabeth, and Melissa, who were educated in Bosnia, Romania, and Poland, also confirmed that some sort of discrimination did happen and that some of the students were even mocked if they were not well prepared for the oral exam. This negative aspect of oral assessment could also be related to the questions of fairness and anxiety.

The results of this thesis showed that the professors' espoused beliefs about mathematics assessment are determined by their prior schooling and teaching experience, the school culture, and the study program within the assessment culture. These results are supported by the research which showed that past school experiences, early family experiences, and teacher education programs where they were trained can influence the teachers' beliefs about mathematics (Raymond, 1997). Also, these thesis results are supported by three categories of experiences that can influence beliefs about teaching, which are: personal experiences, experiences with schooling and instruction, and experiences with formal knowledge (Richardson, 1996).

Besides beliefs, the autonomy of the mathematics teacher also depends on the social context, which can constrain the teacher's freedom of choice and action (Ernest, 1989). According to Raymond (1997), the social teaching norms, immediate classroom situations, and personality traits of the teacher influence the teachers' beliefs about mathematics teaching practices. This thesis extends this research to also include mathematics professors and post-secondary mathematics instructors. Moreover, in this thesis, the results are confirmed that the professors' mathematics assessment practices are determined by the social and the cultural contexts of the teaching situation, in other words, the socio-cultural norms.

The two main causes for the mismatch between espoused beliefs and enacted practices are the influence of the social context and the institutionalized curriculum (Ernest, 1989). These are also present in this thesis. The espoused beliefs about written and oral mathematics assessment are subject to constraints and opportunities of the teaching context, determined by the socio-cultural norms that exist within the specific teaching cultures. In this thesis, these are referred as the oral and the written assessment cultures. Based on each of these two teaching cultures, the professors' enacted mathematics assessment practices are either consistent or not with their espoused beliefs about mathematics assessment.

Now, looking at the main research question of this thesis, "*What factors influence mathematics professors' views on oral assessment in mathematics?*", there are certain factors that influence the participants' views on oral assessment in mathematics. The participants' views of oral assessment in mathematics are based on their own prior schooling and teaching experiences. Moreover, some participants face many constraints within their teaching institution and mathematics department, which affect their current enacted mathematics assessment practices. Also, the participants' enacted assessment practices and their views are certainly influenced by the social context of the teaching culture. Therefore, the following factors influence the professors' views on oral assessment in mathematics:

- schooling and teaching experiences with oral assessment in mathematics ('evidential views' - views held on the basis of evidence);

- the lack of schooling and teaching experiences with oral assessment in mathematics ('non-evidential views' – views held on the basis of no evidence or contrary to evidence);
- the institutionalized mathematics assessment norms (the adopted mathematics assessment practices by the teaching institution and mathematics department);
- the socio-cultural assessment norms (the adopted mathematics assessment practices in oral and written assessment cultures).

6.2 Contributions

The study revealed the extension of Ernest's model of relationships between beliefs and their impact on practice. The modified Ernest's model was presented as Figure 4.1 in Chapter 4 on page 42 (see Figure 4.1 below). The extension includes an addition of views of the nature of mathematics assessment, and espoused and enacted models of mathematics assessment. No previous research has put much focus on studying the relationships between the professors' views on mathematics assessment and mathematics assessment practice.

The research also demonstrated description of the relationships between the professors' espoused beliefs of written and oral assessment in mathematics, and their impact on enacted mathematics assessment practice. This was presented as Figure 4.2 in Chapter 4 on page 43 (see Figure 4.2 below).

Moreover, the study demonstrated description of the relationships between the professors' espoused beliefs about mathematics and mathematics assessment, and their impact on enacted mathematics assessment practice within the oral and written assessment cultures. This was presented as Figure 5.2 in Chapter 5 on page 77 (see Figure 5.2 below). Once again, no previous research has put much attention on discussing the professors' beliefs on written and oral mathematics assessment specifically, and their impact on mathematics assessment practice.

Lastly, this study provided insight into the relationships between professors' concerns with implementing and discontinuing oral assessment in oral and written assessment cul-

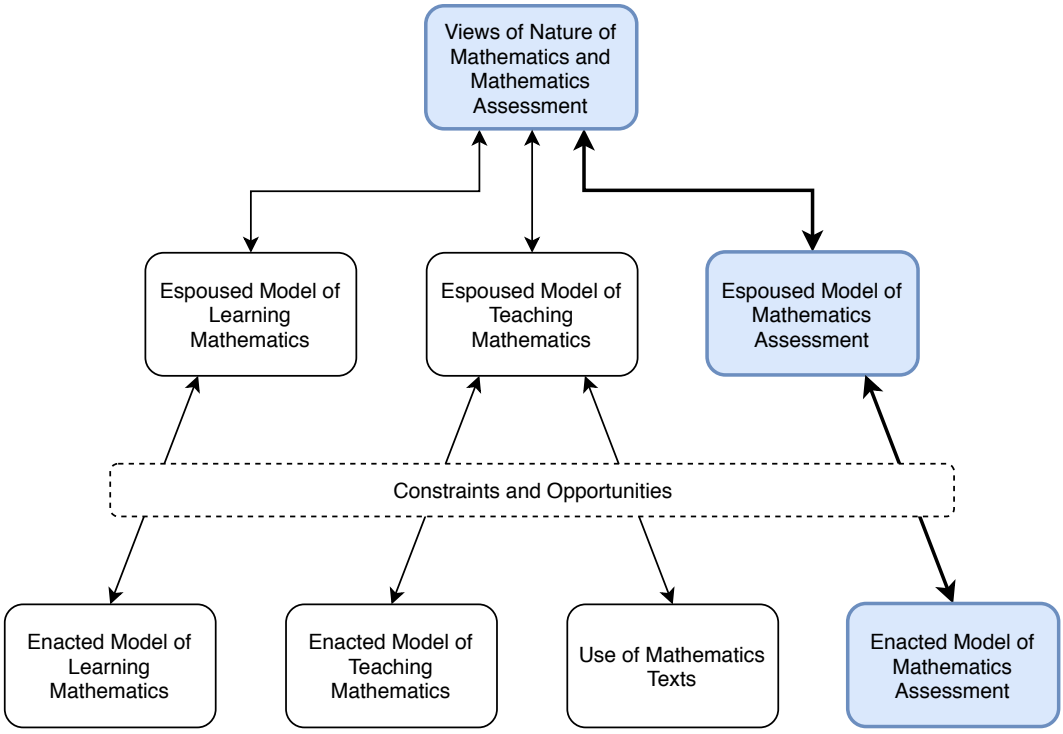

Figure 4.1: Modified Version of Figure 3.1: Relationships Between Beliefs, and Their Impact on Practice

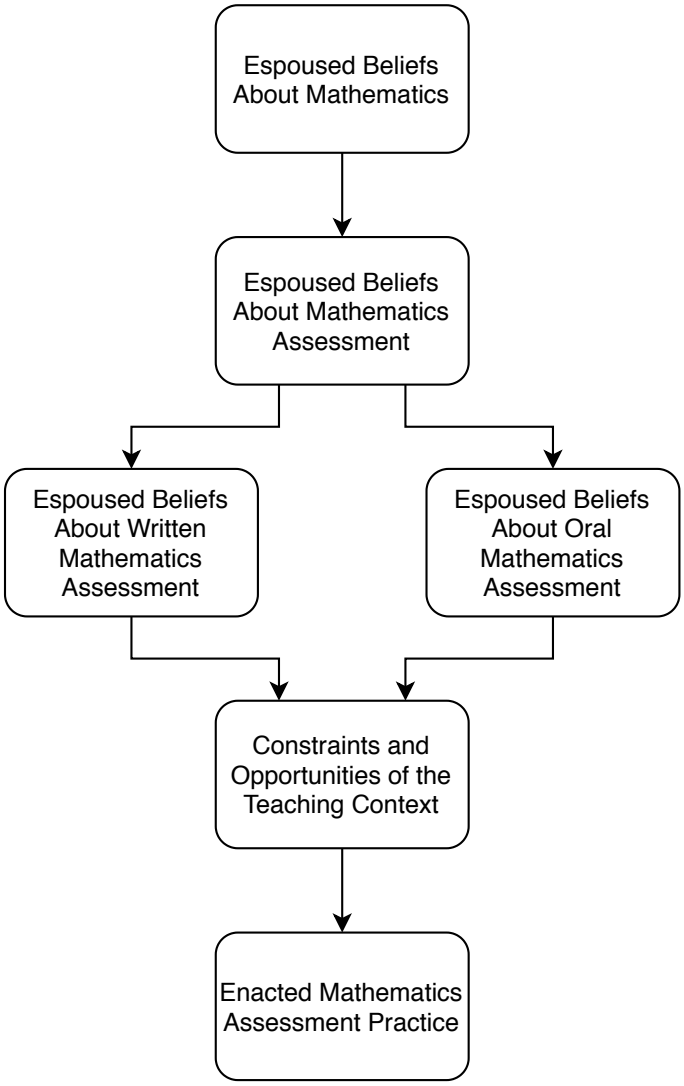

Figure 4.2: Relationships Between Espoused Beliefs of Written and Oral Assessment in Mathematics, and Enacted Mathematics Assessment Practice

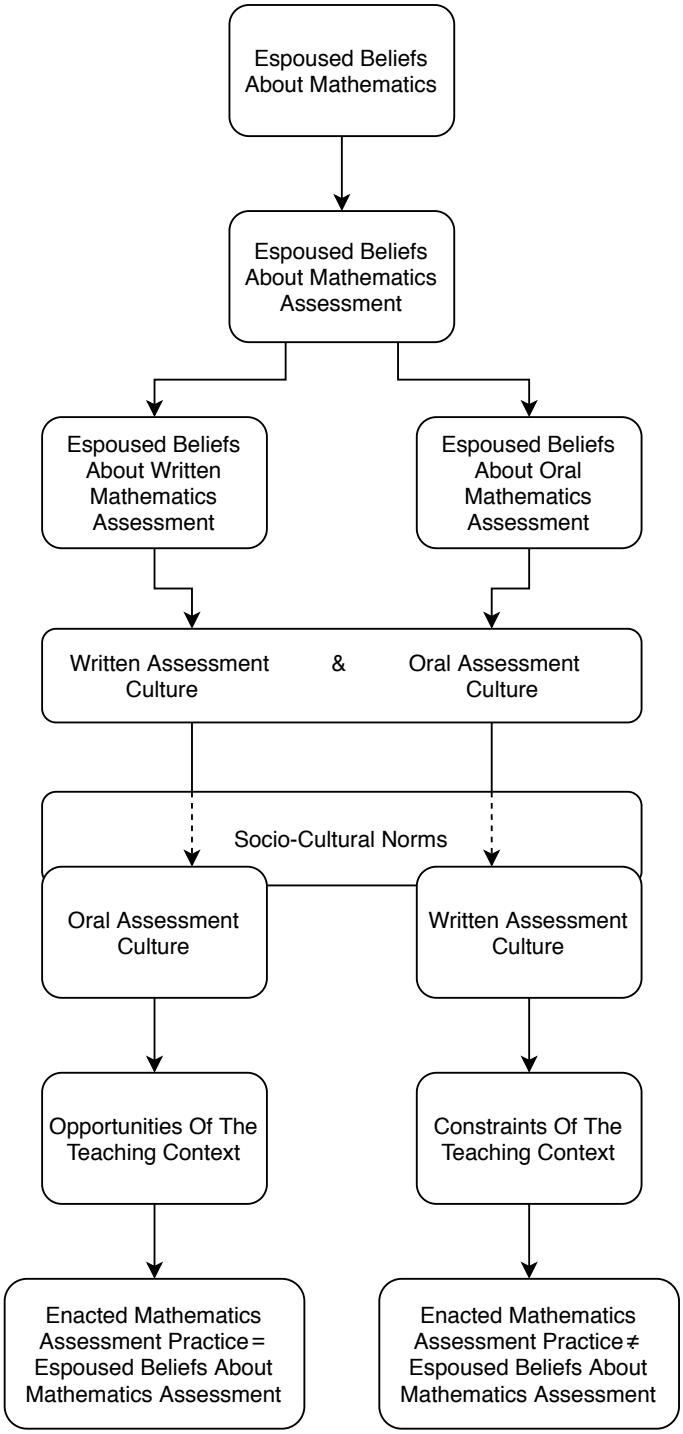

Figure 5.2: Participants' Espoused Beliefs about Mathematics and Mathematics Assessment, and Their Impact on Enacted Mathematics Assessment Practice Within the Oral and Written Assessment Cultures

tures. These were presented as Figure 5.3 and Figure 5.4 in Chapter 5 on pages 81-82 (see Figure 5.3 and Figure 5.4 below). No previous research discusses any of this.

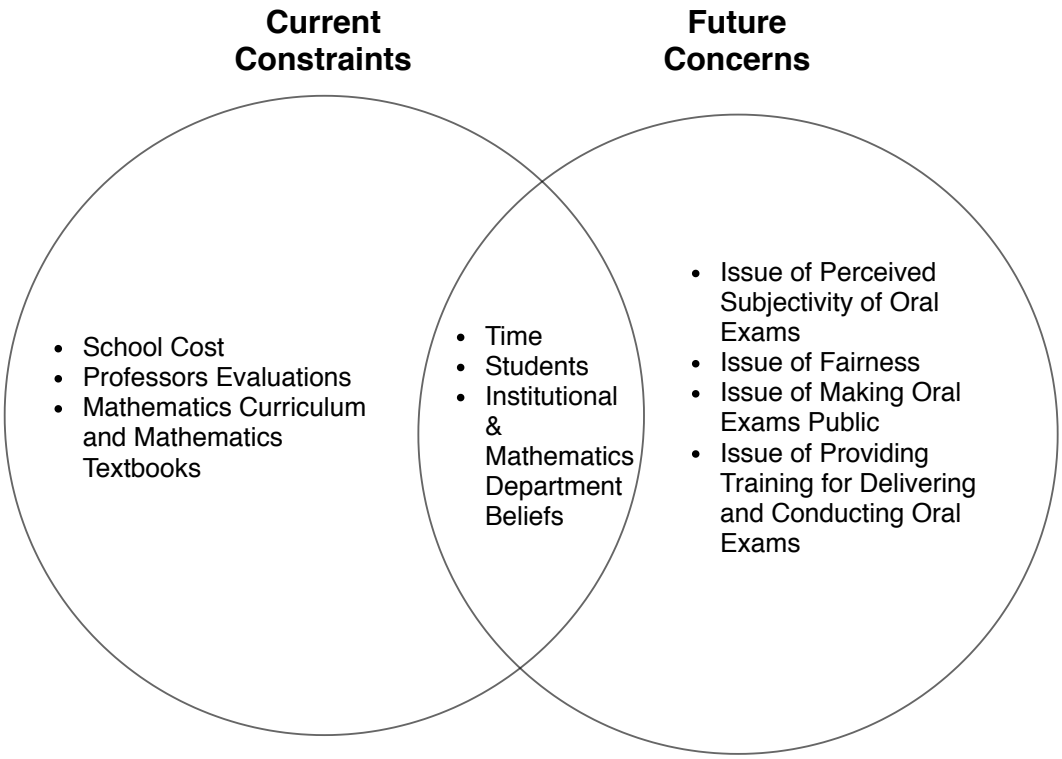

Figure 5.3: Current and Future Common Concerns with Implementing Oral Assessment in Written Assessment Cultures

How these contributions to the study could be adapted to different situations has not been tested yet, but it would be an interesting continuation to this study. These contributions provided the basis for important insights into mathematics professors' experiences of oral assessment in oral and written assessment cultures. However, the results as they are in this study are by no means generalizable.

6.3 Limitations and Future Research

When it comes to limitations of the findings, the study is conducted in a context that includes participants who were very successful as students in learning mathematics. Therefore, this is an important factor in participants' perceptions of mathematics assessment. If interviewees of this study were people who were not successful in mathematics subject

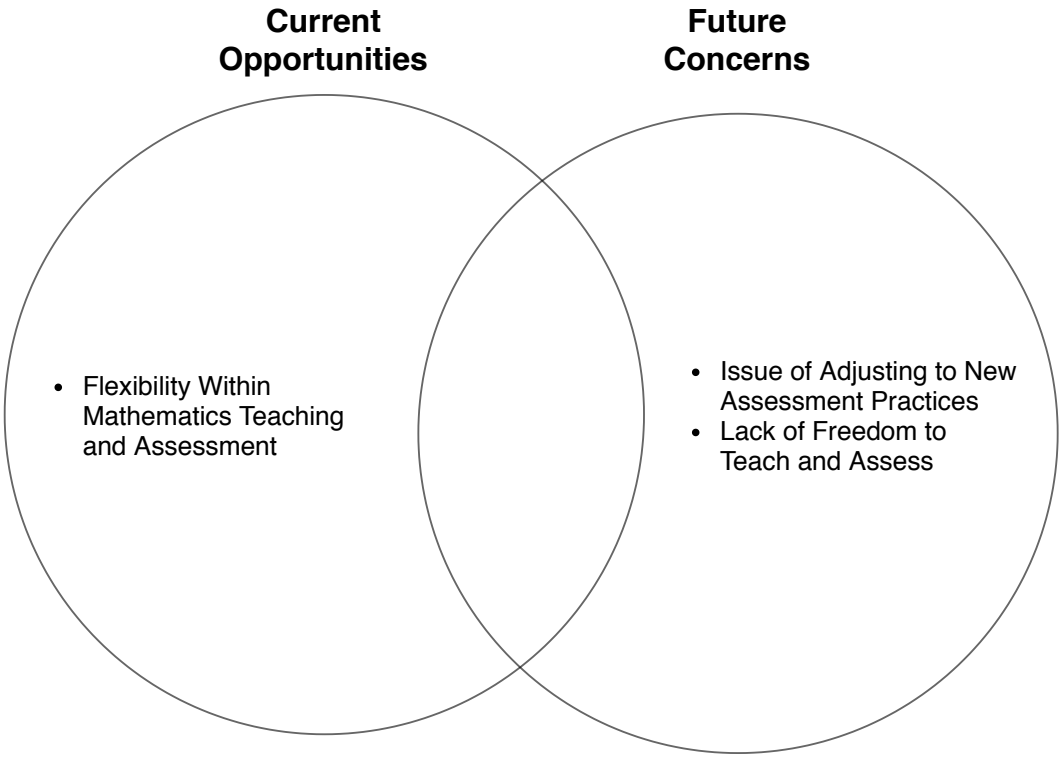

Figure 5.4: Current and Future Common Concerns with Discontinuing Oral Assessment in Oral Assessment Cultures

as students, then they may have a different experiences and views about mathematics assessment. Also, the data used in this study are derived from a single interview with each interviewee. Other sources of data and other research methods can be used to study other aspects of the oral assessment context and experience.

Furthermore, at the beginning of section 4.2.2., I mentioned that this thesis is limited to study mainly the origin of mathematics professors' beliefs about mathematics assessment and mathematics assessment practice from different schooling and teaching cultures, and how these beliefs about mathematics assessment and mathematics assessment practice affect mathematics professors' teaching and assessment practices.

The results of this thesis produced many new findings that were not discussed in depth because of the limitations of this study that were set in section 4.2.2. in relation to choosing particularly the qualitative research method for data collection and analysis, and to focus only on professors' beliefs about mathematics assessment and mathematics assessment prac-

tice, specifically written and oral mathematics assessment. So, based on the new findings, the following research topics are recommendations for possible future research studies:

- to perform a quantitative study in order to understand whether these beliefs and various factors that we were able to understand from this thesis expand to a larger population of mathematics professors from different schooling and teaching cultures;
- to compare mathematics professor – student interaction during the teaching in oral and written assessment cultures;
- to study specific mathematics problems that are more appropriate for oral and written mathematics exams;
- to compare students' oral and written responses on oral and written mathematics exams in order to see which response meets the standard of what is considered a satisfying mathematical answer (for instance, to video record an oral examination in mathematics classroom).

6.4 Final Words

It is very important for me to mention that in this study I am not trying to depreciate written assessment, but merely to encourage mathematics professors to continue or to begin using oral assessment in their mathematics courses as well as to help promote discussion with their colleagues and students on this matter. Moreover, this thesis can serve as a guide to anyone who is about to experience the transition in their teaching of mathematics, moving from oral assessment culture to written assessment culture and vice versa.

As this study focuses on the cultural aspects of mathematics assessment and studies the mathematical practices in particular cultures, I hope that this study can help for gaining better understanding of the importance of acknowledging the students' and the teachers' cultures, and how their cultures affect their thinking and learning of mathematics, and mathematics assessment. From this study we can see that in some cultures, students do not have the option to be orally assessed in mathematics classroom even though there are many countries that still maintain an oral assessment as an important part of their mathematics

assessment practices, but rather they are expected to assimilate prescribed mathematics assessment practices that exist within the particular university culture. I do believe that it is necessary to incorporate oral assessment into mathematics curricula and mathematics assessment practices.

My research journey started with an intention to provide some insights on oral assessment in mathematics, hoping that these insights could inspire some mathematics teachers and professors to think about the possibility of implementing the oral method of assessment in their classrooms. Despite my personal experiences with the oral assessment, through this research I have had a chance to learn something new as well. For instance, throughout my schooling in Serbia, I knew that the oral assessment in mathematics was an important part of assessment practice, but I did not know exactly why that was. From this research, I learned that assessment of particular knowledge and understanding in mathematics implies either written assessment for assessing procedural knowledge and instrumental understanding or oral assessment for assessing conceptual knowledge and relational understanding. I was not aware of this until I started interviewing my participants. Moreover, this research became very personal to me. It allowed me to reflect on my previous schooling experiences and bring some memories from my undergraduate studies. As many participants in this research, I was also a witness of seeing some of my classmates feeling intimidated or mocked by an examiner during the oral examination. This sort of behavior was quite common to experience at that time because of the way how the system of education was structured and because of the certain freedom given to university professors. Again, this had nothing to do with the nature of the oral examination but rather with the personality of the examiner. After all, as a researcher, I was able to learn one thing and that is to always think about students' needs when it comes to their learning and success. Therefore, my goal as a researcher is to make mathematics assessment more meaningful and useful to the students in their learning of mathematics. Hopefully, this research is just a beginning of a long journey that does not need to end along with this PhD study.

Bibliography

Badger, J. (2010). Assessing reflective thinking: pre-service teachers' and professors' perceptions of an oral examination. *Assessment in Education: Principles, Policy & Practice*, 17(1):77–89.

Beswick, K. (2007). Teachers' beliefs that matter in secondary mathematics classrooms. *Educational studies in mathematics*, 65(1):95–120.

Black, P., Harrison, C., Lee, C., Marshall, B., and Wiliam, D. (2004). Working inside the black box: Assessment for learning in the classroom. *Phi delta kappan*, 86(1):8–21.

Boedigheimer, R., Ghrist, M., Peterson, D., and Kallemyn, B. (2015). Individual oral exams in mathematics courses: 10 years of experience at the air force academy. *Primus*, 25(2):99–120.

Brown, G. (2008). *Conceptions of assessment: Understanding what assessment means to teachers and students*. Nova Science Publishers.

Brown, S. and Knight, P. (1994). *Assessing learners in higher education*. Psychology Press.

Brown Jr, J. (1999). *Assessment Matters in Higher Education. Choosing and Using Diverse Approache.s*. Suffolk: The Society for Research into Higher Education & Open University Press.

Cobb, P., Yackel, E., and Wood, T. (1993). Chapter 3: Theoretical orientation. *Journal for Research in Mathematics Education. Monograph*, pages 21–122.

Cooney, T. J. (1985). A beginning teacher's view of problem solving. *Journal for research in mathematics education*, 16(5):324–336.

Cross, D. I. (2009). Alignment, cohesion, and change: Examining mathematics teachers' belief structures and their influence on instructional practices. *Journal of Mathematics Teacher Education*, 12(5):325–346.

De Vita, G. and Case, P. (2003). Rethinking the internationalisation agenda in uk higher education. *Journal of further and higher education*, 27(4):383–398.

Dionne, J. J. (1984). The perception of mathematics among elementary school teachers. In *Proc. 6th Annual Meeting of the North American Chapter of the Int. Group for the Psychology of Mathematics Education*, pages 223–228.

Ernest, P. (1989). The impact of beliefs on the teaching of mathematics. *Mathematics teaching: The state of the art*, pages 249–254.

FairTest: The National Center for Fair and Open Testing (May 22, 2012). What's wrong with standardized tests. `www.fairtest.org/facts/whatwron.htm`.

Forrest, G. M. (1985). Oral examinations. in t. husen, & t. n. postlethwaite (eds.). *The International Encyclopedia of Education*, pages 3688–3688.

Fyhn, A. B. (2015). How a local oral examination considers affective aspects of knowing mathematics. In *CERME 9-Ninth Congress of the European Society for Research in Mathematics Education*, pages 1174–1180.

Gold, B. (1999). Assessment practices in undergraduate mathematics. *Mathematical Association of America*, pages 143–145.

Green, T. F. (1971). The activities of teaching.

Handal, B. (2003). Teachers' mathematical beliefs: A review. *The Mathematics Educator*, 13(2):47–57.

Henderson, J., Lloyd, P., and Scott, H. (2002). 'in the real world we're all put on the spot at some time or other, so you need to be prepared for it': an exploratory study of an oral method of assessing knowledge of mental health law. *Social work education*, 21(1):91–103.

Hiebert, J. and Lefevre, P. (1986). Conceptual and procedural knowledge in mathematics: An introductory analysis. *Conceptual and procedural knowledge: The case of mathematics*, 2:1–27.

Hounsell, D., Falchikov, N., Hounsell, J., Klampfleitner, M., Huxham, M., Thomson, K., and Blair, S. (2007). Innovative assessment across the disciplines. *An analytical review of the literature. Final Report. HEA*.

Hubbard, J. (1971). Measuring medical education. *Philadelphia: Lea and Febiger*.

Huxham, M., Campbell, F., and Westwood, J. (2012). Oral versus written assessments: A test of student performance and attitudes. *Assessment & Evaluation in Higher Education*, 37(1):125–136.

Iannone, P. and Simpson, A. (2011). The summative assessment diet: how we assess in mathematics degrees. *Teaching Mathematics and its Applications: An International Journal of the IMA*, 30(4):186–196.

Iannone, P. and Simpson, A. (2012). Oral assessment in mathematics: implementation and outcomes. *Teaching Mathematics and Its Applications: International Journal of the IMA*, 31(4):179–190.

Iannone, P. and Simpson, A. (2015). Students' views of oral performance assessment in mathematics: straddling the 'assessment of' and 'assessment for' learning divide. *Assessment & Evaluation in Higher Education*, 40(7):971–987.

Joughin, G. (1998). Dimensions of oral assessment. *Assessment & Evaluation in Higher Education*, 23(4):367–378.

Joughin, G. (2007). Student conceptions of oral presentations. *Studies in Higher Education*, 32(3):323–336.

Joughin, G. (2010). *A short guide to oral assessment*. Leeds Met Press in association with University of Wollongong.

Karaagac, M. K. and Threlfall, J. (2004). The tension between teacher beliefs and teacher practice: The impact of the work setting. *International Group for the Psychology of Mathematics Education*.

Lianghuo, F. and Mei, Y. (2007). Integrating oral presentation into mathematics teaching and learning: An exploratory study with singapore secondary students. *The Montana Mathematics Enthusiast, Monograph*, 3:81–98.

Liljedahl, P. (2009). Teachers' insights into the relationship between beliefs and practice. *Beliefs and attitudes in mathematics education: New research results*, pages 44–54.

Liljedahl, P. (2010). The four purposes of assessment. *Vector*, 2:4–12.

Maasz, J. and Schlöglmann, W. (2009). *Beliefs and attitudes in mathematics education: New research results*. Sense publishers.

Nelson, M. A. (2010). Oral assessments: Improving retention, grades, and understanding. *PRIMUS*, 21(1):47–61.

Nor, H. and Shahrill, M. (2014). Incorporating the use of poster and oral presentations as an alternative assessment in the teaching of secondary mathematics. In *Proceedings of the 2nd International Conference on Social Sciences Research*, pages 369–378. ICSSR 2014, WorldConferences. net Kota Kinabalu, Sabah, Malaysia.

Noyes, A. (2004). (re) producing mathematics educators: A sociological perspective. *Teaching Education*, 15(3):243–256.

O'Connor, K. (2009). *How to grade for learning, K-12*. Corwin Press.

Odafe, V. U. (2006). Oral examinations in college mathematics. *PRIMUS*, 15(3):243–256.

Ortiz-Robinson, N. L. and Ellington, A. J. (2009). Learner-centered strategies and advanced mathematics: A study of students' perspectives. *Primus*, 19(5):463–472.

Philipp, R. A. (2007). Mathematics teachers' beliefs and affect. *Second handbook of research on mathematics teaching and learning*, pages 257–315.

Raymond, A. M. (1997). Inconsistency between a beginning elementary school teacher's mathematics beliefs and teaching practice. *Journal for research in mathematics education*, 28(5):550–576.

Richardson, V. (1996). The role of attitudes and beliefs in learning to teach. *Handbook of research on teacher education*, 2:102–119.

Roecker, L. (2007). Using oral examination as a technique to assess student understanding and teaching effectiveness. *Journal of Chemical Education*, 84(10):1663–1666.

Romagnano, L. (2001). The myth of objectivity in mathematics assessment. *Mathematics Teacher*, 94(1):31–37.

Roos, B. and Hamilton, D. (2005). Formative assessment: A cybernetic viewpoint. *Assessment in Education: Principles, Policy & Practice*, 12(1):7–20.

Skemp, R. R. (1976). Relational understanding and instrumental understanding. *Mathematics teaching*, 77(1):20–26.

Skott, J. (2001). The emerging practices of novice teachers: The roles of his school mathematics images. *Journal of Mathematics Teacher Education*, 4(1):3–28.

Skott, J. (2015). The promises, problems, and prospects of research on teachers' beliefs. *International handbook of research on teachers' beliefs*, pages 13–30.

Smith, M. L. and Fey, P. (2000). Validity and accountability in high-stakes testing. *Journal of Teacher Education*, 51(5):334–344.

Stipek, D. J., Givvin, K. B., Salmon, J. M., and MacGyvers, V. L. (2001). Teachers' beliefs and practices related to mathematics instruction. *Teaching and teacher education*, 17(2):213–226.

Stray, C. (2001). The shift from oral to written examination: Cambridge and oxford 1700–1900. *Assessment in Education: Principles, Policy & Practice*, 8(1):33–50.

Stylianou, D. A. and Blanton, M. L. (2002). Sociocultural factors in undergraduate mathematics: The role of explanation and justification. In *Proceedings of the Second International Conference on the Teaching of Mathematics, Crete, Greece*. Citeseer.

Suurtamm, C., Thompson, D. R., Kim, R. Y., Moreno, L. D., Sayac, N., Schukajlow, S., Silver, E., Ufer, S., and Vos, P. (2016). *Assessment in Mathematics Education*, pages 1–38. Springer International Publishing, Cham.

Thompson, A. G. (1992). Teachers' beliefs and conceptions: A synthesis of the research. *Handbook of research on mathematics teaching and learning*, pages 127–146.

Törner, G. and Grigutsch, S. (1994). Mathematische weltbilder bei studienanfängern – eine erhebung. *Journal für Mathematikdidaktik*, 15(3/4):211–252.

Vacc, N. N. and Bright, G. W. (1999). Elementary preservice teachers' changing beliefs and instructional use of children's mathematical thinking. *Journal for research in mathematics education*, pages 89–110.

Vogt, W. P. (1999). Dictionary of statistics and methodology: A nontechnical guide for the social sciences.

Willson, M. and Cooney, T. J. (2002). Mathematics teacher change and development: The role of beliefs. *Beliefs: A hidden variable in mathematics education*, pages 127–147.

Yackel, E. and Cobb, P. (1996). Sociomathematical norms, argumentation, and autonomy in mathematics. *Journal for research in mathematics education*, 27:458–477.

Yackel, E., Rasmussen, C., and King, K. (2000). Social and sociomathematical norms in an advanced undergraduate mathematics course. *The Journal of Mathematical Behavior*, 19(3):275–287.

Yoon, C., Kensington-Miller, B., Sneddon, J., and Bartholomew, H. (2011). It's not the done thing: social norms governing students' passive behaviour in undergraduate mathematics lectures. *International Journal of Mathematical Education in Science and Technology*, 42(8):1107–1122.

Žalská, J. (2012). Mathematics teachers' mathematical beliefs: A comprehensive review of international research. *Scientia in educatione*, 3(1):45–65.

Appendix A

Consent Form

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SIMON FRASER UNIVERSITY

CONSENT FORM

Title: Professors' Views of Oral Assessment in Mathematics Classroom

Investigator: Milica Videnovic

Investigator Department: Education

You, as a university/college mathematics professor, have been invited to participate in a research study (named above) conducted by Milica Videnovic. Before you give your consent, it is important that you read the following information and ask as many questions as necessary to be sure you understand what you will be asked to do.

Purpose of the study:

The purpose of the study is to look into mathematics university/college professors' perspectives on oral assessment, in which each of the professors has already been exposed to this type of assessment, either as a student during his/her undergraduate/graduate studies and/or as a teacher/professor during his/her teaching of mathematics.

The goal is to provide information as to how the oral assessment can be implemented in mathematics classroom, and what are their advantages and disadvantages in comparing with written assessment.

Procedures:

You will be asked through oral conversation to participate in an interview. Participation in interview is voluntary. During the interview, you will also be asked to verbally respond

to questions related to your personal experiences with oral assessment in mathematics classroom, either as a student during your undergraduate/graduate studies and/or as a teacher/professor during your teaching of mathematics. These will be a combination of direct questions, as well as some that are more open ended. Your responses will be recorded using a portable recording device, and saved to a USB memory drive, which will only be used for the purposes of this study.

Risks:

There are no risks associated with this study. Refusal to participate, or withdrawal from the study at any point, will have no adverse effects on your employment or evaluation. In addition, no permission will be sought from organizations that employ my research participants.

Benefits:

There may or may not be any benefits to participating in this research. This research will inform university/college professors as well as high school teachers about different assessment methods, with the particular emphasis on oral assessment, in mathematics classrooms. In addition, it will inform their pedagogical decisions, so that their students can fully benefit from this form of assessment. Teacher educators will have the benefit of being able to make informed decisions about how to support teachers in creating different forms of assessment in their classrooms and filling the existing gaps that exist in using the current forms of assessment. Though they are not the intended audience, the most effected stakeholders are of course the students who will benefit directly from professors and teachers effectively using different forms of assessment in their mathematics classrooms.

Confidentiality:

Audio recordings for interviews will be obtained using a portable recording device, and stored on a USB memory drive, as well as a second back up drive, which will be used solely for the purpose of the study. Written notes and coded data will also be stored on the same USB memory drive. When not in use, the USB memory drive, all transcribed data, both electronic and printed, and signed consent forms will be stored in a locked cabinet inside of a locked office and will only be accessed by my supervisor and myself.

The recordings will be heard and transcribed only by my supervisor and me, and transcription will occur within two weeks of individual interviews. The data will be coded, and direct identifiers such name, gender or other information that could serve to identify participants will not be included in the reported data, or the dissemination of the results. There will be no secondary uses for the recordings.

Direct quotes may be used in the dissemination of the results, but no identifiers such as name or gender will be used. Responses from participants will be kept strictly confidential, and will not be discussed in general terms or disclosed in any way to other participants. All audio recordings and data will be kept in a locked drawer in a private locked office and will be destroyed as soon as possible after transcription to ensure confidentiality.

Voluntary Nature of Participation:

Your decision to participate or withdrawal after agreeing to participate will have no adverse affect on your employment or evaluation. Should you wish to withdraw, any recordings and data associated with your participation will be destroyed. Your participation in this research study will be extremely helpful to me and other mathematics educators who look towards improving assessment in mathematics, and we look forward to working with you.

If you have any questions related to the study, you should contact Milica Videnovic at #########. Should you wish to obtain information about your rights as a participant in research, or about the responsibilities of researchers, or if you have any questions, concerns or complaints about the manner in which you were treated in this study, please contact the Director, Office of Research Ethics, by email at ##########, or by phone at #########.

Agreement:

Your signature on this form will signify that you have read the information in this agreement, which describes the purpose, procedures, possible risks and benefits of this research study, that you have received an adequate opportunity to consider the information in the document, and that you voluntarily agree to participate in the study. Alternatively, your returning this form via email will signify that you have read the information in this agreement, which describes the purpose, procedures, possible risks and benefits of this research study, that you have received an adequate opportunity to consider the information in the document, and that you voluntarily agree to participate in the study.

Consent Form

Name of Participant (PRINT):

I certify that I understand the procedures to be used.

Signature of Participant:

And I know that I have the right to withdraw from the study at any time, and that any complaints about the study may be brought to:

#########,

Director, Office of Research Ethics

Simon Fraser University

By email at #########

Or by phone #########

I may obtain copies of the results of this study, upon its completion by contacting the researcher named below:

Milica Videnovic

########

Please clearly write YES or NO in response to the following question:

Do you consent to being audio recorded? _____

Print Name of Participant: _____

Signature of Participant: _____

Date: _____

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