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ORAL VS. WRITTEN EXAMS: WHAT ARE WE ASSESSING IN MATHEMATICS?

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Abstract. One of the most striking differences between the Canadian educational system and most European educational systems is the importance given to oral examinations, particularly in mathematics courses. In this paper, seven mathematics professors share their views on mathematics assessment, and their thoughts about the types of knowledge and understanding in mathematics that can be assessed on written and oral exams. Four out of seven professors were born and educated in Bosnia, Poland, Romania, and Ukraine, and they are currently teaching in Canada. The other three professors were born and educated in Canada, the United States, and Germany, and they are all currently teaching in Germany. With the increased emphasis on closed book written examinations, the results in this study show that written exams alone are not sufficient to assess students' conceptual knowledge and relational understanding, and therefore, there is a critical need for implementing the oral assessments in mathematics courses.

Keywords: oral examination, mathematics professors, knowledge, understanding

Introduction

For many years the primary method of assessment in mathematics classroom has seemed to be strictly based on closed book written examinations. The USA in particular appears to be dominated by closed book examinations [4, 13]. Iannone and Simpson [7] note that the majority of mathematics students in the UK seem to be assessed predominately using high stakes, closed book examinations at the end of almost every module. Joughin [10] argues that the structure of the assessments today are either closed and formal, with little interaction between student and assessor(s), or open, with less structure and the opportunity for dialogue between student and assessor(s). Ernest [2] believes that conversation lies at the heart of mathematics and that mathematical knowledge representations are conversational, consisting of symbolically mediated exchanges between persons as well as claiming that, "the ancient origins and various modern systems of proof are conversational, through dialectic or dialogical reasoning, involving the persuasion of others" (p. 205). When it comes to different types of oral assessment, according to Joughin [11], 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 the doctoral viva); and application (where candidates apply their knowledge live

in a simulated situation, e.g., having trainee doctors undertaking live diagnoses with an actor-patient). Although oral assessment is used in many areas, there is very little literature examining the use of oral assessments. Hounsell, Falchikov, Hounsell, Klampfleitner, Huxham, Thompson and Blair [6] note in their comprehensive review of the literature on innovative assessment that less than 2% of the papers address the oral assessments. They reviewed the recent UK literature on 'innovative assessment' and of 317 papers considered, only 31 dealt with 'non-written assessments.' Within this category, only 13% addressed the use of oral examinations. Today, there are many countries that still maintain an oral assessment as an important part of their assessment diet, such as Hungary, Italy and the Czech Republic [17]. Germany is also one of them.

Oral Examination in Mathematics

In most of the cases, 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. 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': $\int \arcsin^2 x \, dx$).

Theoretical Framework

Skemp [16] introduced two perspectives of mathematics, relational understanding as knowing both what to do and why, and instrumental understanding as the ability to execute mathematical rules and procedures. On the other hand, Hiebert and Lefevre [5] contrasted two perspectives of mathematics, conceptual and procedural knowledge, defining both of them as:

Conceptual knowledge:

> Knowledge that is rich in relationships. It 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. Relationships pervade the individual facts and propositions so that all pieces of information are linked to some network (p. 3-4).

Procedural knowledge:

> One kind of procedural knowledge is a familiarity with the individual symbols of the system and with the syntactic conventions for acceptable configurations of symbols. The second kind of procedural knowledge consists of rules or procedures for solving mathematical problems. Many of the procedures that students possess probably are chains of prescriptions for manipulating symbols (p. 7-8).

After having numerous discussions with some mathematics professors in Canada as well as in the United States, I realized that oral examination in mathematics courses at university level is not present at all even though there is a number of research that indicate that oral assessments have a positive impact on students' learning of mathematics [1, 3, 8, 9, 13, 14, 15]. 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" [18, p. 131]. In this paper, the following research question was investigated: *What are the mathematics professors' views on the nature of mathematics assessment?*

Methodology

The research design for this study is descriptive/qualitative. Seven participants were interviewed using open-ended questions to gather information about their personal experiences and perspectives on using written and oral assessments in mathematics classroom. These participants were selected based on the following criteria: each participant has been exposed to oral assessment either as a student, teacher, and/or professor. In terms of recruitment, I used a methodology of snowballing, wherein 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 or using oral assessment. Seven mathematics professors were selected for interviews: Melissa, Elisabeth, Van, Nora, Dave, James, and Jane. 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 examination in mathematics prior 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 prior moving to Germany. James was born and educated in Germany, and thus, he has had a lot of exposure to oral assessment in mathematics. The audio recordings of interviews were transcribed and transcriptions were used for data analysis.

Results

There are three aspects of the results that will be discussed in this section:

- What do participants value about oral assessment over written assessment?
- Where do participants' views on oral assessment come from?
- What types of knowledge and understanding can be measured using oral assessment as compared to written assessment?

What do participants value about oral assessment over written assessment?

When it came to the nature of mathematics assessment, it seemed that most of the participants valued students' ability to explain their reasoning and understanding of mathematical concepts, in relation to the oral examination. The following comments exemplify this:

> "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).*
> … "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 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).*

Where do participants' views on oral assessment come from?

It seemed that one of the main sources of participants' views of mathematics assessment came from their own prior schooling experience. Oral examinations in mathematics were part of the educational system in some of the participants' prior schooling and teaching experience, therefore, oral exams were considered to be an essential and natural part of examination process, from primary to higher education. The following comments support this:

> … "so, 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 oral exams play an important part in assessment process in mathematics was related to the culture and study program of the university where they are teaching. The following comment exemplifies 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…" *(James).*

On the other hand, the oral exams could cause discomfort to those who had never been exposed to it, as being something that is not completely natural or familiar. Dave commented:

> "…[It] is primarily I guess if you like a cultural issue… I think there's 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."

What types of knowledge and understanding can be measured using oral assessment as compared to written assessment?

Based on the participants' responses on what could be assessed in oral and written exams in mathematics, it seemed that there was a clear division between the views of participants who had previously been exposed to oral assessments in mathematics and the one who had not. Their views were presented in Table 1.

Table 1. Written and oral exams: What are we assessing?

Examination Type	**What Are We Assessing?**	**Participants**
Written	Procedural knowledge/Instrumental understanding	Van; James; Melissa; Nora; Elisabeth
	Procedural knowledge/Instrumental understanding Conceptual knowledge/Relational understanding	Dave; Jane
Oral	Conceptual knowledge/Relational understanding	Van; James; Melissa; Nora; Elisabeth

All five participants, Van, James, Melissa, Nora and Elisabeth, who had been previously exposed to oral assessments in mathematics, agreed that written exams could mostly assess procedural knowledge and instrumental understanding while oral exams could better assess conceptual knowledge and relational understanding. On the contrary, the other two participants, Dave and Jane, who had never been previously exposed to oral assessments in mathematics prior coming to Germany, believed that the written exam alone could efficiently assess both procedural knowledge and instrumental understanding and conceptual knowledge and relational understanding. The following two subsections contain comments supporting each of these views.

Oral Exams: Conceptual knowledge/Relational understanding
Written Exams: Procedural knowledge/Instrumental understanding

> "In the homework written assignments I would say more procedural…. procedural in the sense of computational. So, conceptual in the sense of abstract arguments… more oriented towards prove this and that statement" (*James).*
> "I guess in written maybe you can assess procedural. You can see if they could follow a strategy for solving an equation. But I guess relation, yeah it's more-- You can do that I guess better with oral" (*Elisabeth).*
> "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" *(Nora).*
> "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, you know, if this is given and this is given, then find this or find that" *(Van).*
> "In most cases those questions were sort of follow up of the written exam questions both to check understanding or maybe give students opportunity to correct but also to look deeper into student's thinking." (*Melissa).*

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

> **"**Explain to me what the derivative is … . 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."

Written Exams: Procedural knowledge/Instrumental understanding and Conceptual knowledge/Relational understanding

> … "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 whether there's such good questions" *(Dave).*

Jane also felt that conceptual questions, theory, and proofs could be better assessed in writing than orally and when asked for an example of a question that could not 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 tended to need just more time to think about things."

Discussion and Conclusion

Mathematical problems that could better assess procedural knowledge and instrumental understanding, participants considered types of problems that would require some sort of computational skills. On the other hand, when it came to mathematical problems that would better assess conceptual knowledge and relational understanding, participants considered theoretical type 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 could be only answered through written exam. On the other hand, they considered the questions that could be answered quickly to be sort of "procedural" questions, and only these types of questions could be assessed orally.

Overall, if we acknowledge that each student learns differently, then having a common approach to assessment would be inadequate. Educators accept the need for differentiated instruction in order to deal with the individuality and variability of students, and thus, they also need to accept the need for differentiated assessment to represent the learning of the fractured student collective [12]. Also, it is very important for me to mention that in this paper I am not trying to depreciate written assessment, but merely to argue for a balanced diet of the most appropriate assessment methods for the students. I hope that the ideas and examples that I was able to present in this paper will encourage many mathematics educators 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.

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