Guidelines for the Mathematics Education Qualifying Exams for August 2024

Exam format: The exam will consist of two sections: One section for content from MTH 761 and one section for content from MTH 762. There will be two questions for you to answer for each section on the exam. The exam will likely be conducted in the Mac Computer Lab (Pearce 404) and the computers will be disconnected from the Internet. You will be given the exam on a USB memory drive and you will save your responses on that drive.

Exam grade:
A grade of 70% or better on each part of the exam separately will be considered a passing score. In mathematics education, we build our arguments with words. In MTH 761 and MTH 762, we discussed how to form an argument in mathematics education (and how this might differ from a proof in mathematics). While we will not be judging students' creative writing ability in the qualifying exam, we will judge your ability to form and express a coherent and reasoned argument about mathematics education using reasonable composition standards. You are expected to synthesize across the articles from class and the readings completed for your individual projects for the courses. You will then use them to build and argue your own points in addressing the qualifying exam questions.

Exam Content: In MTH 761 and MTH 762, you read practitioner pieces, theoretical works, and empirical research studies utilizing qualitative, quantitative, and mixed methods research approaches. It is beyond human memory to recall all small details of each article and so this is not expected of you. In practice, mathematics education researchers routinely re-read relevant articles for such details. For the qualifying exam, however, you are expected to understand the main themes discussed in these courses and in the articles. We expect that you can compose well-reasoned arguments, based on these themes, that demonstrate your knowledge of the teaching and learning of mathematics. Furthermore, you should be able to critique research studies in mathematics education and determine the relevance of the results for the teaching and learning of mathematics.

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MTH 761:
The following are some of the topics and readings with which you should be familiar. A general understanding of discussions from class is also expected. While you should be familiar with the following papers, the main source for applying the research in MTH 761 will come from the course text, Liljedahl, P. (2020). *Building thinking classrooms in mathematics: 14 teaching practices for enhancing learning, grades K-12*. Corwin.

1. Development of Symbolic Reasoning
    a. Kieran, C., & Sfard, A. (1999). Seeing through Symbols: The Case of Equivalent Expressions. *Focus on Learning Problems in Mathematics*, *21*(1), 1-17.
    b. Sfard, A., & Linchevski, L. (1994). The Gains and the Pitfalls of Reification--The Case of Algebra. *Educational Studies in Mathematics*, *26*(2-3), 191-228.
    c. Sfard, A. (1991). On the Dual Nature of Mathematical Conceptions: Reflections on Processes and Objects as Different Sides of the Same Coin. *Educational Studies in Mathematics*, *22*(1), 1-36.
    d. Kaput, J. J., Blanton, M. L., & Moreno, L. (2008). Algebra from a symbolization point of view. In J. J. Kaput, D. W. Carraher, & M. L. Blanton (Eds.), *Algebra in the early grades* (pp. 19-55). New York, NY: Taylor and Francis Group.

2. Use of Representations
    a. Cory, & Garofalo, J. (2011). Using Dynamic Sketches to Enhance Preservice Secondary Mathematics Teachers' Understanding of Limits of Sequences. *Journal for Research in Mathematics Education*, *42*(1), 65–97. https://doi.org/10.5951/jresematheduc.42.1.0065
    b. Demir, M., & Zengin, Y. (2023). Investigation of generalisation processes of secondary school students using multiple representations in a pattern task. *International Journal of Mathematical Education in Science and Technology*, 1–28.
    c. Lapp, D.A., Ermete, M., Brackett, N., & Powell, K. (2013). Linked representations in algebra: Developing symbolic meaning. *Mathematics Teacher*, *107*(*4*), 306-312.
    d. Leinhardt, G, Zaslavsky, O, and Stein M. (1990) Functions, Graphs and Graphing: Tasks, Learning and Teaching. *Review of Educational Research*, *60*(1), 37-42.
    e. Tall, D., & Vinner, S. (1981). Concept image and concept definition in mathematics with particular reference to limits and continuity. *Educational Studies in Mathematics*, *12*(2), 151-169.

3. Theories of Learning
    a. Borasi, R. (1994). Capitalizing on Errors as "Springboards for Inquiry": A Teaching Experiment. *Journal for Research in Mathematics Education*, *25*(2), 166-208.
    b. Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410-8415.

   c. Pirie, S. and Kieren, T. (1994). Growth in mathematical understanding: How can we characterize it and how can we represent it? *Educational Studies in Mathematics*, *26*, 165-190.
   d. Sriraman, B. & English, L. (2005). Theories of mathematics education: A global survey of theoretical frameworks/trends in mathematics education. *ZDM-The International Journal on Mathematics Education*, *37*(6), 450–456.

4. Use of Technology
   a. Campbell, & Zelkowski, J. (2020). Technology as a Support for Proof and Argumentation: A Systematic Literature Review. *International Journal for Technology in Mathematics Education*, *27*(2), 113–124.
   b. Ellington, A. J. (2006). The Effects of Non-CAS Graphing Calculators on Student Achievements and Attitude Levels in Mathematics: A Meta-Analysis. *School Science & Mathematics*, *106*(1), 16-26.
   c. Heid, M. K. (1988). Resequencing skills and concepts in applied calculus using the computer as a tool. *Journal for Research in Mathematics Education*, *19*(1), 3–25.
   d. Palmiter, J. R. (1991). Effects of computer algebra systems on concept and skill acquisition in calculus. *Journal For Research In Mathematics Education*, *22,* 151-156.

5. Content Specific Teaching and Learning
   a. Appova, A. & Berezovski, T. (2016). Technology-Based Geometry Activities for Teaching Vector Operations. *Mathematics Teacher*, *109*(7), 542-545.
   b. BeltrÁn-Meneu, Murillo-Arcila, M., & Albarracín, L. (2017). Emphasizing Visualization and Physical Applications in the Study of Eigenvectors and Eigenvalues. *Teaching Mathematics and Its Applications*, *36*(3), 123–135. https://doi.org/10.1093/teamat/hrw018
   c. Dawkins, P. C. (2015). Explication as a lens for the formalization of mathematical theory through guided reinvention. *The Journal of Mathematical Behavior*, *37*, 63–82.
   d. Fukawa-Connelly. (2016). Responsibility for proving and defining in abstract algebra class. *International Journal of Mathematical Education in Science and Technology*, *47*(5), 733–749. https://doi.org/10.1080/0020739X.2015.1114159
   e. Larsen, S.P. (2013). A local instructional theory for the guided reinvention of the group and isomorphism concepts. *Journal of Mathematical Behavior*, *32*(4), 712-725.
   f. Larsen, S. & Lockwood, E. (2013). A local instructional theory for the guided reinvention of the quotient group concept. *Journal of Mathematical Behavior*, *32*(4), 726-742.

6. In addition to familiarity with the readings given above, you will be expected to apply these ideas to classroom and curricular situations in ways described in Liljedahl (2020). While the stated readings are a basic expectation, since one the of the purposes of this exam is to allow you to creatively respond to issues in mathematics education, you should also feel free to draw upon other reading you have done in the field as you frame your responses.

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MTH 762:
The following are some of the topics and readings with which you should be familiar. A general understanding of how to critique studies and identify the strengths and weaknesses of articles is expected.

Overview of Mathematics Education Research (including a counterexample):

a. Chapter 1 of textbook (McKnight et al., 2000)
b. Chapter 2 of textbook (McKnight et al., 2000)
c. Chapter 11 of textbook (McKnight et al., 2000)
d. Schoenfeld, A. H. (2000). Purposes and methods of research in mathematics education. *Notices of the AMS*, *47*(6), 641-649.
e. Cai, J., Morris, A., Hohensee, C., Hwang, S., Robison, V., Cirillo, M., ... & Hiebert, J. (2019). Posing significant research questions. *Journal for Research in Mathematics Education*, *50*(*2*), 114-120.
f. Cullinane, M. J. (2011). Helping mathematics students survive the post-calculus transition. *PRIMUS*, *21*(8), 669-684.

Quantitative Research:

a. Chapter 3 of textbook (McKnight et al., 2000)
b. Chapter 4 of textbook (McKnight et al., 2000)
c. Chapter 5 of textbook (McKnight et al., 2000)
d. Wood, P. M., & Bhute, V. (2019). Exploring student perception toward online homework and comparison with paper homework in an introductory probability course. *Journal of college science teaching*, *48*(5), 68-75.
e. MacNell, L., Driscoll, A., & Hunt, A. N. (2015). What's in a name: Exposing gender bias in student ratings of teaching. *Innovative Higher Education*, *40*(4), 291-303.

Qualitative Research (including task-based interviewing):

a. Chapter 6 of textbook (McKnight et al., 2000)
b. Chapter 7 of textbook (McKnight et al., 2000)
c. Chapter 8 of textbook (McKnight et al., 2000)
d. Creswell, J. W., & Miller, D. L. (2000). Determining validity in qualitative inquiry. *Theory into practice*, *39*(3), 124-130.
e. Maher, C. A., & Sigley, R. (2020). Task-based interviews in mathematics education. *Encyclopedia of mathematics education*, 821-824.
f. Dibbs, R. (2019). Forged in failure: engagement patterns for successful students repeating calculus. *Educational Studies in Mathematics*, *101*(*1*), 35-50.
g. Weber, K., Mejía-Ramos, J. P., & Volpe, T. (2022). The relationship between proof and certainty in mathematical practice. *Journal for Research in Mathematics Education*, *53*(1), 65-84.

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Additional Research Methods (including mixed methods, teaching experiments, meta-analyses, and comprehensive literature reviews):

a. Chapter 9 of textbook (McKnight et al., 2000)
b. Bogdan, R. & Biklen, S. (2007). Applied qualitative research for education. In *Qualitative Research for Education: An Introduction to Theories and Methods, Fifth Edition* (pp. 219-248). Pearson.
c. Stylianou, D. A., Blanton, M. L., & Rotou, O. (2015). Undergraduate students' understanding of proof: Relationships between proof conceptions, beliefs, and classroom experiences with learning proof. *International Journal of Research in Undergraduate Mathematics Education*, *1*, 91-134.
d. King, E. H. (1978). College mathematics: Open vs lecture. *Improving College and University Teaching*, *26*(1), 50-51.
e. Schroeder, L. B., McGivney-Burelle, J., & Xue, F. (2015). To flip or not to flip? An exploratory study comparing student performance in calculus I. *Primus*, *25*(9-10), 876-885.
f. Güler, M., Kokoç, M., & Önder Bütüner, S. (2023). Does a flipped classroom model work in mathematics education? A meta-analysis. *Education and Information Technologies*, *28*(1), 57-79.
g. Miller, D. I., Nolla, K. M., Eagly, A. H., & Uttal, D. H. (2018). The development of children's gender-science stereotypes: A meta-analysis of 5 decades of US Draw-a-Scientist studies. *Child development*, *89*(6), 1943-1955.
h. Finson, K. D. (2002). Drawing a scientist: What we do and do not know after fifty years of drawings. *School science and mathematics*, *102*(7), 335-345.

Assessment and Evaluation:

a. Chapter 10 of textbook (McKnight et al., 2000)
b. CMU Mathematics Department's 2021-2022 BA/BS Assessment Report
c. CMU Department of Mathematics External Review Report, 2023
d. CMU Mathematics Department's Program Review 2023–2024 SWOT and Draft Plan for Improvement

You are also welcome to draw on any of your readings that you did for our class projects.