Programming-Based Mathematics Inquiry: The Biggest Challenges Faced by Students During Course Projects, and How they Handle Them

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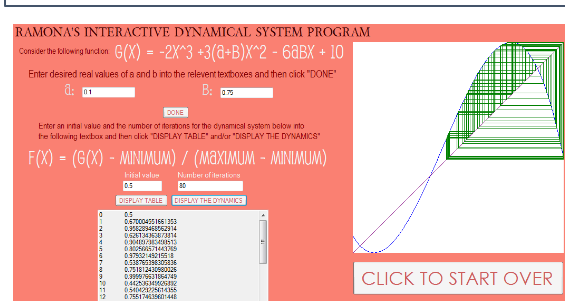
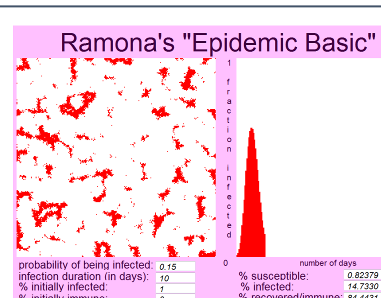
Introduction

- There has been a growing interest in studying and implementing innovative approaches in undergraduate mathematics, such as inquiry-based mathematics education (Artigue & Blomhøj, 2013; Laursen & Rasmussen, 2019).
- In particular, programming can support a certain inquiry-based approach, where students engage in computational practices used by some professional mathematicians (Weintrop et al., 2016).
- In their recent "Call for Research that Explores Relationships between Computing and Mathematical Thinking and Activity," Lockwood and Mørken (2021) argue that "serious consideration of machine-based computing [including programming] is largely absent from much of our research in undergraduate mathematics education" (p. 2). They suggest that much more needs to be investigated, "including identifying and exploring potential benefits, affordances, **challenges**, and problematic issues" (ibid.).
- We address this gap, using the opportunity provided by the natural MICA environment. As part of our study, we seek to better understand the challenges students face during their learning, which we see as potentially providing insights for implementation.

Context

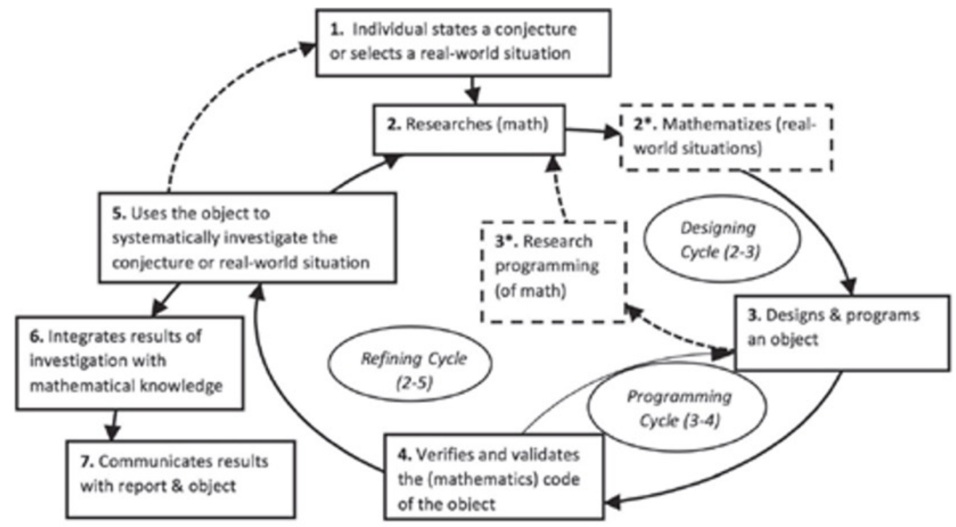
- We work in the context of a sequence of three courses called Mathematics Integrated with Computers and Applications (MICA), which have been implemented at Brock University since 2001. These courses engage students in a sequence of 14 projects, in which they design, program, and use interactive computer environments to investigate mathematics concepts, conjectures, theorems, or real-world situations (Buteau et al., 2015).





Theoretical Framework

- We view students' learning through the developmental process model in which students' engagement involves steps that appear in a dynamic, non-linear fashion, similar to the process of mathematicians conducting research.
- We also use the instrumental approach in which programming is seen as an artefact (human product) that may be transformed into a meaningful instrument, through a process called instrumental genesis. This involves students' development of a web of schemes, i.e. interrelated schemes found at different steps of the dp-model.



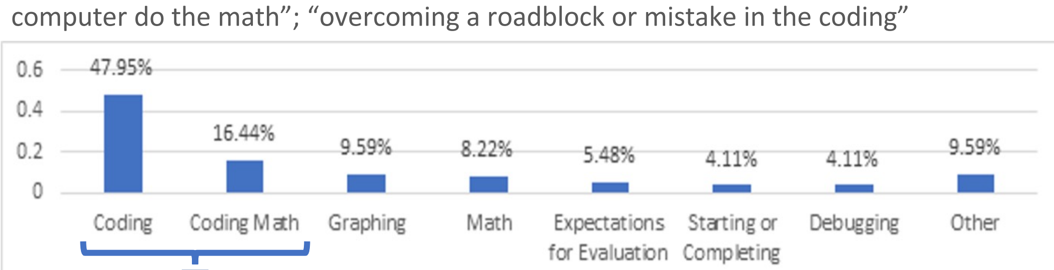
Methodology

- This poster focuses on students' responses to a post-course online questionnaire- specifically short responses to the questions asking 'what' they found most challenging, 'why,' and 'how' they mostly handled it.
- We systematically examine the challenges (i.e. aspects of students' engagement that appear to cause the most issues, in terms of schemes, steps from the dp-model, or more general elements) that students face and how students mostly handle them (i.e. to move their mathematical inquiry forward) through the thematic coding of (N=73) student' responses, creation of graphical representations, and interpretation using our theoretical framework.

Findings

What challenges do undergraduate mathematics students encounter when engaging in programming-based mathematics inquiry projects?

e.g. "anything that requires a loop, an array, or long segments of code"; "making the computer do the math"; "overcoming a roadblock or mistake in the coding"



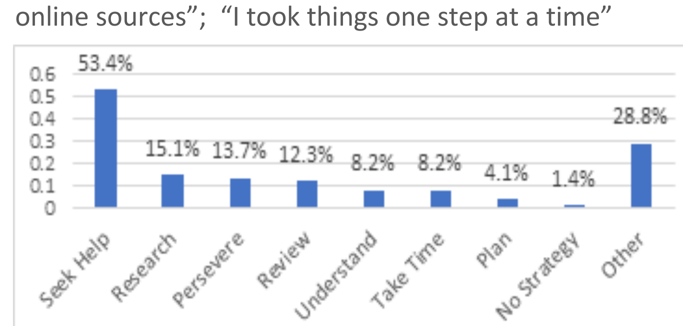
How do students explain their challenges (of coding and coding math)?

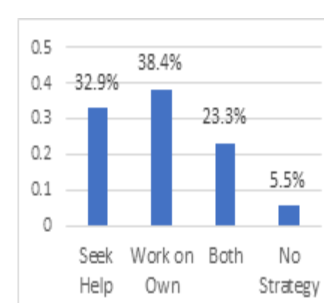
e.g. "…sometimes I don't know how to approach the math in a programming sense"; "one small thing can throw the whole code off"

Struggle to mobilize/develop certain schemes	Nature of Instrumental Genesis	Nature of Artefact	Nature of Mathematics
• Starting or getting stuck with coding (32.6%) • Efficiency of code (6.5%)	• Coding (math) is new (15.2%) • Need more guidance (10.9%) • Not confident in coding (6.5%) • Need more time (4.3%)	• Coding is finicky or picky (13%) • Struggling to understand how a program works (6.5%)	• Difficulty thinking computationally (4.3%) • Struggling with coding complicated or brand new math (4.3%)

How do they handle their challenges?

e.g. "speak with peers and the professor in order to get on the right track"; "trying to structure out some sort of design before writing programs"; "Using the textbook and online sources"; "I took things one step at a time"





MICA I vs Upper MICA (MICA II and III):

- MICA I students solely sought help more than Upper MICA students (38.5% vs. 26.5%). Upper MICA students indicated solely working through it on their own more than MICA I students (47.1% vs. 30.8%).
- This may point to upper MICA students being more comfortable working independently in programming-based mathematics inquiry projects and that they may be further along in their instrumental genesis.

Females vs Males:

- Overall similar. However, females appear to do both strategies more often than males (27% vs 16%) and males tend to have no strategy more often (12% vs 2%).

Broley, L., Buteau, C., Levay, D., Marshall, N., Muller, E., Sardella, J., Mgombelo. J., & Sacristán, A. I. (in press). Students Facing and Handling Challenges in Programming-Based Mathematical Inquiry Projects. In *Proceedings of the 24th Annual Conference on Research in Undergraduate Mathematics Education*. Boston, MA.

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