Features of 'Authentic' Programming-based Mathematical Tasks

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Introduction/Context

- There is a resurgence of interest in integrating programming, more broadly **computational thinking** (**CT**), in education (Benton et al., 2017)[8];
- This reflects scientific fields that have developed a computational counterpart (Weintrop et al., 2016)[1] & the rise of a **21st century skill and need** for proficiency in computational practices.
- Weintrop et al. (2016) argue for **'authentic' computational tasks** in math and science classes, providing a taxonomy of computational practices[1]
- Our interest is in CT **curriculum** development and **task** design that would **equip students with skills and competencies to address this need**, in relation to programming for math learning.

Methodology

- We view students' learning through the concept of "legitimate peripheral participation"[3]
- This poster focuses on the **features of 'authentic' tasks in which students engage peripherally in CT for mathematics practices as mathematicians do**[1]
- We analyze the 14 project-based tasks from a sequence of 3 programming-based math courses, *Mathematics Integrated with Computers and Applications* (MICA) at Brock University:
- We explored the relevance of **affordances of CT** for mathematics learning (Gadanidis et al., 2017) **in the work of mathematicians**;[4] then examined the 14 tasks to identify common task features.

CT-based Math Project Tasks* (since 2001[5])

**accounting for 70-80% of students' final grades*
**used in Buteau et al.'s (2016) study[5] — see the latter for details*

- EO1. Conjecture about primes or hailstone sequences
- EO2. RSA encryption method
- EO3. Discrete dynamical system (cubic with two parameters)
- **EO4. Original project for which students select the topic themselves**
- EO5. Areas & Monte Carlo integration
- EO6. Stats application to stock market
- EO7. Synchronization of traffic lights (in pairs)
- EO8. Markov chains applied to income demographics & chronic illness
- **EO9. Original project for which students select the topic themselves**
- EO10. Discrete dynamical system of the logistic function & bifurcation diagram
- EO11. Simulation of battles (Lanchester equations)
- EO12. Prey-predator biological model (Lotka-Volterra)
- EO13. Cellular automata, simulation of epidemics & costs
- **EO14. Original project for which students select the topic themselves**

Task Analysis

	Dynamic Modelling	Conceptual surprise	Tangible feel	Abstraction & automation	Agency
Affordances of Computational Thinking for Mathematics Learning (Gadanidis et al., 2017)[4]	• Changing code immediately illustrates the "mathematical reaction" (p. 79)[4] • Programming is an *object to think with*[6], to conjecture and to explore	• Dynamic modelling "increases the potential for students to experience the pleasure of mathematical surprise" (p. 80)[4]	• When translated into code, mathematical concepts develop a tangible feel[4] • Such concepts can be "manipulated, listed, printed, drawn" (p. 80)[4]	• Programming is a means for mathematicians to automate their work, which is made more efficient or even possible (e.g. dynamic visualizations)	• Students are in control when they write code[4] • Experience CT and mathematics as producers and consumers by creating their own programs[4]
In the Work of Mathematicians 	• In dynamic modelling, "the choice of models goes hand in hand with the computational tools and the mathematical analysis"[7]	• Mathematicians work on unknown math • Broley et al. (2017) discuss how a mathematician spoke with excitement about her discovery[2]	• Mathematicians use and aim for visual and dynamic representation in CT-based research • Visualizations lead to discoveries that would be otherwise unseen[2]	• Mathematicians use programming to "compute 'amazing things' that are 'not computable' by traditional methods" (p. 2520)[2]	• Agency is natural to researchers in any discipline who research what they are passionate about and as such is meaningful to them and to their community
MICA **In EO3** **Features for "Authentic" Programming-Based Math Tasks**	• In EO3, students explores the system graphically and numerically • Students use their EO to find parameter values leading to a periodic behaviour	• The discrete dynamical system of EO3 is unknown to students • Students can experience surprise as a mathematician would	• EO3 task includes the dynamic graphical construction of the system cobweb • The tangible feel affordance is observed as a visual representation	• EO3 involves the investigation of a discrete dynamical system • The focus is on interpretation through simulations	• EO3 is one of three pure mathematics project tasks • Relies on the development of the instructor to trigger students' curiosity. Many other EOs are applications
	Should lead to conjecturing/exploring of unknown mathematics (to the students)		**(Dynamic) visualization**	**Cannot be done by hand**	**Meaningful to students**

Analysis of Curriculum Design

	Wide walls	Low floor-high ceiling
Affordances of Computational Thinking for Mathematics Learning (Gadanidis et al., 2017)[4]	• Computer coding supports a variety of project types[4] • Individuals with diverse interests can all be engaged in the task[4]	• Students can "engage with minimal prerequisite knowledge (low floor) with more complex concepts (high ceiling)" (p. 83)[4]
Curriculum Design MICA	• MICA integrates variety in the 11 assigned tasks and 3 final project tasks for which students select their own topic. • Range of pure and applied math topics	• MICA I students learn computational concepts within an accessible related mathematics context • Tasks are open to investigations and explorations
	Diversity in CT-based mathematics task collection	**Careful sequencing of CT-based tasks**

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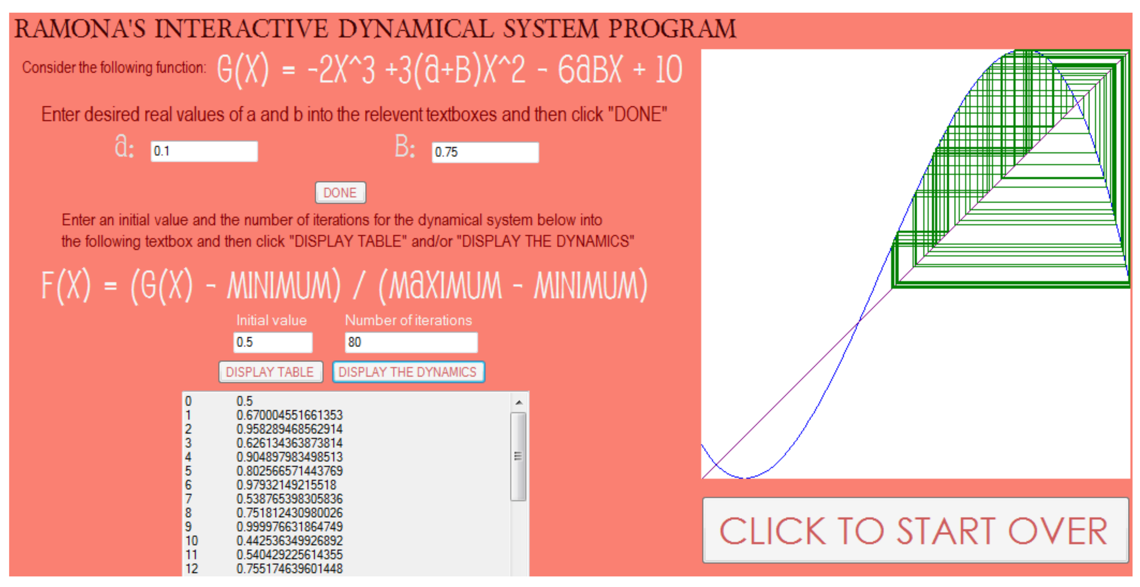
Sample CT-based Math Project Task (EO3)

Design, program, then use an interactive environment to **explore, graphically and numerically,** the discrete dynamical system based on a cubic (with 2 parameters): find pairs of parameter values leading to a periodic behaviour.[5]



Concluding Remarks

- Our task analysis guided by CT affordances for mathematics learning (Gadanidis et al., 2017)[4] led to identify **4 features for 'authentic' programming-based mathematical tasks**
- Our curriculum analysis highlights **a possible task sequencing to support novices' CT development for math investigations and applications** (as a **21st Century skill**)
- Our current 5-year long SSHRC-funded research focuses on examining students' CT development throughout their overall curriculum over three academic terms

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