Examining Synergistic Learning of Physics and Computational Thinking through Collaborative Problem Solving in Computational Modeling

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C²STEM

Overview

The research presented in this poster is guided by the question: *What is the nature of collaborative problem solving during computational modeling? What insights can an examination of productive collaborative problem solving during computational model building provide into the synergistic learning of physics and CT?*

C2STEM Highlights

- ✓ **Challenge-based, evidence-centered design** of STEM curricula to meet NGSS & state science standards
- ✓ **Low threshold, wide walls, high ceiling**: accomplished using domain-specific block structured languages to support learning
- ✓ **Coupled multi-level representations** to support learning: conceptual modeling & inquiry components offer new forms of exploring & decomposing STEM domain
- ✓ **Synergistic Learning**: emphasis on integrating CT with existing science curricula – complements CS4All programs
- ✓ **Simultaneous assessments for STEM & CT**: Utilize ECD & PFL assessments for studying learning performance and behaviors
- ✓ **Collaborative model building** to support interaction & problem-solving skills
- ✓ **Involve teachers** in curriculum development and support for classroom activities

Theoretical Framework

OECD CPS Framework

OECD (2013) defines the Collaborative Problem Solving competency as "the capacity of an individual to effectively engage in a process whereby two or more agents attempt to solve a problem by sharing the understanding and effort required to come to a solution, and pooling their knowledge, skills, and effort to reach that solution" (p. 9).

	(1) Establishing and maintaining shared understanding	(2) Taking appropriate action to solve the problem	(3) Establishing and maintaining team organisation
(A) Exploring and understanding	(A1) Discovering perspectives and abilities of team members	(A2) Discovering the type of collaborative interaction to solve the problem, along with goals	(A3) Understanding roles to solve the problem
(B) Representing and formulating	(B1) Building a shared representation and negotiating the meaning of the problem (common ground)	(B2) Identifying and describing tasks to be completed	(B3) Describe roles and team organisation (communication protocol/rules of engagement)
(C) Planning and executing	(C1) Communicating with team members about the actions to be/being performed	(C2) Enacting plans	(C3) Following rules of engagement, (e.g. prompting other team members to perform their tasks)
(D) Monitoring and reflecting	(D1) Monitoring and repairing the shared understanding	(D2) Monitoring results of actions and evaluating success in solving the problem	(D3) Monitoring, providing feedback and adapting the team organisation and roles

Note: The 12 skill cells have been labelled with a letter-number combination referring to the rows and columns for ease of cross-referencing later in the document.

Collaboration processes	Proficient behaviour (summary)
(1) Establishing and maintaining shared understanding	• Discovers others' abilities and shares information about own ability • Discusses the problem - asks questions, responds to others' questions • Communicates during monitoring and resolution of group work
(2) Taking appropriate action to solve the problem	• Understands the type of interaction needed, makes sure to know who does what • Describes and discusses tasks and task assignment • Enacts plans together with others and performs the actions of the assigned role • Monitors and evaluates others' work
(3) Establishing and maintaining team organisation	• Acknowledges and enquires about roles • Follows rules of engagement - complies with plan, ensures others comply with the plan • Monitors team organisation - notices issues, suggests ways to fix them

Collaborative Discourse Frameworks

We integrate two frameworks:

- ❑ The ICAP framework (Chi & Wylie, 2014), which defines four different modes of engagement when considering learning behaviors: Interactive, Constructive, Active, and Passive.
- ❑ The Weinberger & Fischer framework (2006), analyzes knowledge construction in a collaborative learning environment includes five categories of social modes: externalization, elicitation, quick consensus building, integration-oriented consensus building and conflict-oriented consensus building.

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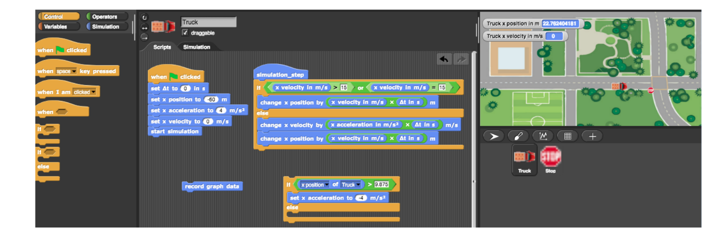
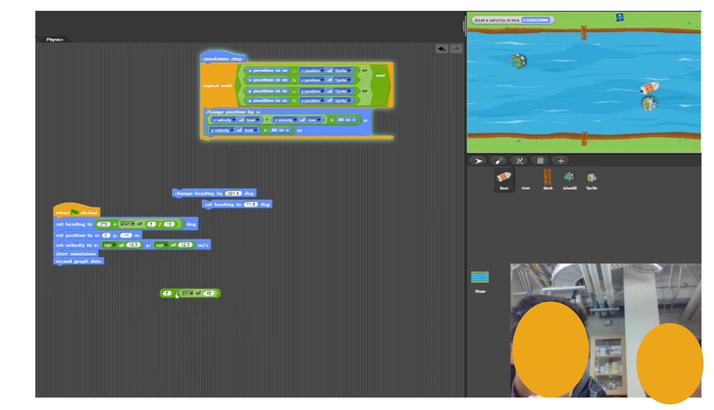
Evidence-Centered Design for Integrated STEM + CT Learning

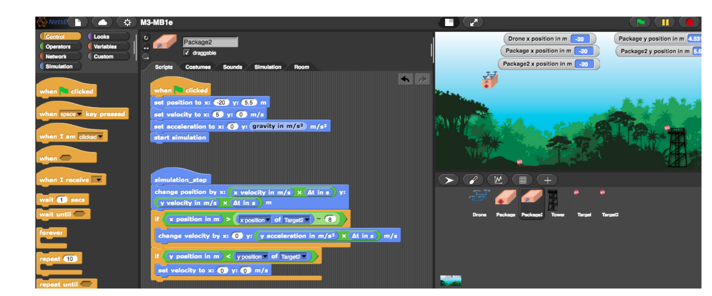
Science Disciplinary Concepts (NGSS Alignment: PS2.A: Forces and Motion
Target Constructs:
1. Relations among position, velocity, speed, and time
2. Relations among acceleration, velocity, time
3. Distinctions among position, displacement, and distance
4. Addition of velocity vectors in one and two dimensions
5. Representation of two dimensional motion as the superposition of independent representations for each dimension
6. Velocity-time and position-time graphs for constant velocity and constant acceleration

Computational Thinking Concepts (K-12 CS Framework Alignment: Algorithms & Programming, Data Analysis)
Target Constructs:
1. Algorithms
2. Initializing and updating variables
3. Operators and expressions
4. Control structures: Event handlers, **conditionals, iterations (as expressed using a simulation step which is an implicit loop in the simulation environment)**
5. Data collection and visualizations as graphs
6. Making inferences and predictions using data visualizations like charts and graphs

Computational Modeling Practices (NGSS practices alignment: Develop & use models; K-12 CS Practices alignment: Creating computational artifacts, Developing & using abstractions, Testing & refining computational artifacts)
Target Constructs:
1. Develop computational models by specifying model elements and representing their relations and interactions
2. Use computational models to explain or predict phenomena
3. Evaluate, test, and debug computational models by determining why the model does or does not appropriately explain or predict the phenomenon
4. Elaborate computational models by modularizing or generalizing model code to new scenarios or problems







Episode 1: Initialization

Set Up: Students work on a 2D constant velocity task where they need to program a boat to cross a river, stopping at two islands on the way. This task requires students to learn 2-D velocity and computation of the result velocity, given the river current.

Student's Words and Actions	Physics and CT	Collaboration Discourse	OECD CPS
S2: "How come you threw that block away?" **S1:** "What, that block? (pointing) Because we've already set the heading." **S2:** "Alright, but when you reset it's..." **S1:** "Right." [**S1** ADDS set heading block under GF and hardcodes to 291.28] **S2:** *jokingly says other student's name* **S1:** "My wits have taken leave."	**CT focused**: S2 challenges S1's removal of one of the blocks —presumably place in the wrong location causing the simulation to reset to an initial value.	**Interactive conflict-oriented consensus building**: S2 challenges S1's action of discarding a set block, S1 tries to explain his reasoning and after further prompting by S2, sees the error	**(C3):** Following rules of engagement (e.g. prompting team members to perform their tasks) **(D2)** Monitoring results of actions and evaluating success in solving the problem
S1: "And then, set position, set velocity" **[S1** ADDS set x velocity block under GF]		**Constructive externalization**: S1 reverts to narrating actions with S2 following along	**Overall:** S2 is monitoring S1's actions and calls out on a potential error made that S1 subsequently fixes. They are (1) Taking appropriate action to solve the problem—enacting plans together and also monitoring and evaluating others' work
S1: "and that's all we need to know, because it won't let us accelerate. It will let us accelerate in 2D air because that is when we start factoring in gravity. So then, start simulation, simulation step." [**S1** ADDS start simulation to GF and simulation step flag]	**Physics focused**: S1 concludes that they have completed the physics required for the model		

Episode 2: Using Conditional Logic

Set Up: Students work on a 1D motion task where students model the motion of a truck that speeds up from rest to a given maximum speed (defined by a speed limit), maintain that speed and slow down and stop at a stop sign. This task requires students to calculate a lookahead distance from a stop sign.

Student's Words and Actions	Physics and CT	Collaborative Dialogue	OECD CPS
S2: "I would think like just like if velocity equals .. like if velocity equals 15 m/s set acceleration to 0 m/s..."	**Physics focused:** S2 attempts to support his reasoning by bringing in the relationship between velocity and acceleration.	**Interactive conflict-oriented consensus building:** S2 challenges S1 again on the choice of conditional structure. After showing S2 on the screen, S1 and S2 develop a common understanding of the physics and CT concepts to use in their model.	**(C1):** Communicating with team members about actions being performed **(C3):** Following rules of engagement (e.g. prompting team members to perform their tasks) **(D1):** Monitoring and repairing the shared understanding
S1: "We could do that but that would be.. eh.. I just I don't like the way that sounds cause yeah but yeah I know what you're saying." **S1:** "Ok so basically if velocity is equal.. is greater than or equal to whatever.. then .change ..then both of these.. else just the bottom part. Ok." **S2:** "Oh I see why you put that there." **S1:** "Exactly"	**CT focused:** S1 shows S2 on the model how his idea would work		

Episode 3: Debugging

Set Up: Students work on a 2D gravity drop motion task where student model the delivery of two packages by a drone, calculating the look-ahead distance needed to release each package in order to safely land each at the desired ground targets.

Student's Words and Actions	Physics and CT	Collaboration	OECD CPS
S1: "Did we miscalculate? Did we miscalculate? Does it need to be like 9 meters or something? Let's try 9 meters just to be sure. I have a sneaky, sneaky suspicion."	**Physics focused**: S1 is pointing out that the physics calculations may be incorrect.	**Interactive integration-oriented consensus building**: S1 and S2 work together to find the error in their model, and they conclude that it is likely a time miscalculation	**(C3):** Following rules of engagement (e.g. prompting team members to perform their tasks) **(D3)** Monitoring, providing feedback and adapting the team organisation and roles.
[**S1** edits subtraction in if via hardcode]. **S1:** "Let's try this again." [**S1** presses play] **S1:** "Drop..." **S2:** "It's not.." **S1:** "Yeah, that's not right." **S2:** "Wait, I want to see it" [**S2** takes control of mouse]	**CT focused:** S1 and S2 are using the model to determine why the package is not ending up in the correct place		
S1: (inaudible) "Did we miscalculate the time?" **S2:** "We might have" **S1:** "We might have miscalculated the time. Let's go back and look at the time equation. We could do this one, too, couldn't we?" **S2:** (agreement sound)	**Physics focused**: After their model does not work as expected, S1 and S2 go back to determining where they made an error in modeling the physics relations.		

Takeaways

★ Examining talk among pairs and triads as they build computational models offers insights into their understanding of Physics & CT concepts, and how they combine them to build models.

★ Through examining collaborative dialogs, we have :

- ★ A better understanding of how students structure and build their simulation model (initialization + update functions);
- ★ A better understanding of the difficulties students have with their (1) domain and CT concepts and practices; and (2) in combining them to build models potential for application in other domains);
- ★ An appreciation of the importance of debugging. Debugging is central to modeling and learning processes; it clearly reflects students' difficulties and if/how they overcome them. Debugging episodes are a rich source for understanding students' cognitive processes & domain + CT knowledge.

Combining CPS & Collaborative Regulation (CR)

Our ongoing efforts involve combining CPS & CR—

- ❖ CR provides us with additional framing for understanding of how students interact – from self-regulation to other regulation to socially shared regulation.
- ❖ Socially shared regulation (SSR) implies "collective regulation where the regulatory processes and products are shared" -- the implication is this leads to more productive behaviors because it reduces the cognitive load on the individual and it leads to truly shared understanding that benefits all partners.
- ❖ By combining the CPS and CR frameworks, we aim to determine how students' regulatory processes influence their cognitive and metacognitive processes, as well as their motivation to work on complex tasks.

Future Directions

- ➢ Extend our analytic model to understand the mutually supportive learning of integrated domains similar to Physics & CT (such as Marine Biology and CT).
- ➢ Develop collaboration scripts that consciously promote socially shared regulation processes and science practices such as argumentation & explanation
- ➢ Design tasks specifically to promote CPS
- ➢ Use and examine system tools for collaboration (e.g. chat)
- ➢ Build adaptive feedback in the system to support CPS

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