SURGE: Integrating Vygotsky's Spontaneous and Instructed Concepts in a Digital Game?

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In Thought and Language, Vygotsky discusses the potential for leveraging intuitive understandings from everyday experience ("spontaneous concepts") with "instructed" scientific concepts to build robust understandings. The question remains whether or not the intuitive spontaneous concepts players develop in through computer games can be successfully leveraged into robust instructed concepts in a manner that transfers to academic assessments and across domains recognized as central by the scientific disciplines themselves. This poster presents data from early studies with the SURGE video game, where students demonstrated significant learning across multiple items of a posttest based on the Force Concept Inventory, suggesting that the sequence and structure of the models and representations designed in the SURGE game are effective in changing how students think about the formal instructed concepts. However, care must be taken to ensure that the ideas that students take away from the game are the ones intended.

Research Goals and Theoretical Framework

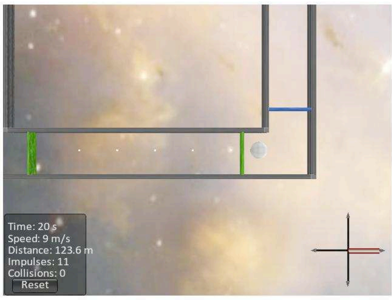
School science, with its focus on explicit formalized knowledge structures, seldom connects with students' tacit intuitive understandings. Interestingly, many commercial video games focus on physics, ecology, engineering, and other critical STEM concepts at their core. Furthermore, commercial video games are exceptionally successful at helping learners build accurate intuitive understandings of the concepts and processes embedded in the games due to the situated and enacted nature of good game design (Gee, 2003, 2004, 2007). As SURGE advisor James Gee explains, good game design is inherently about problem solving. According to Gee, however, these games fall short because they do not help students articulate and connect their evolving tacit intuitive understandings into larger explicit formalized structures allowing knowledge transfer and application across broader contexts. In Thought and Language, Vygotsky (1986) discusses the potential for leveraging intuitive understandings from everyday experience ("spontaneous concepts") with instructed scientific concepts to build robust understandings. The question remains whether or not the intuitive spontaneous concepts developed in games can actually be successfully leveraged into robust instructed concepts in the format and terminology of academic assessment and across domains recognized as central by the scientific disciplines.

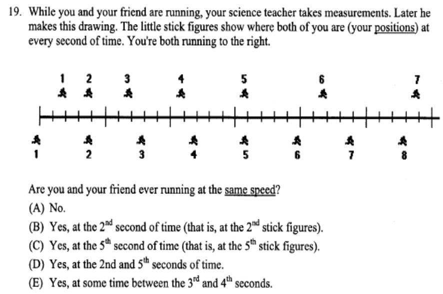
Game Context and Data

SURGE (Scaffolding Understanding by Redesigning Games for Understanding) investigates design principles for connecting students' intuitive "spontaneous concepts" about kinematics and Newtonian mechanics into formalized "instructed concepts." SURGE integrates research on conceptual change, cognitive processing-based design, and socio-cognitive scripting with design principles and mechanics of popular commercial video games such as Mario Galaxy, Switchball, Orbz, and Portal to support students' articulation and connection of their evolving tacit intuitive understandings into larger explicit formalized structures allowing knowledge transfer and application across broader contexts relevant to Newtonian mechanics. SURGE incorporates the game play designs of these games in levels alternating between marble "travel" and marble "launching" in the context of a space-based adventure. Each level involves specific challenges directly linked to physics concepts. To complete these challenges, students need to learn and apply many principles related to mechanics (e.g., impulse, inertia, vector addition, elastic collision, gravity, velocity, acceleration, free-fall, mass, force, projectile motion).Each level highlights one or two topics, and levels allow students to connect the concepts together and to see the relations that exist among the topics. For example, the initial levels do not include gravity or friction. However, as the game progresses, gravity and then friction are gradually introduced. This approach allows students to gain a firm grasp of a concept before new concepts are introduced.

Assessment Methods

Assessment in SURGE involves standard experimental design in terms of random assignment of participants within classrooms across experimental groups. In addition, SURGE is conducting formative quantitative and qualitative analyses of student learning during development/pilot-testing phases. Student learning in SURGE is measured (a) in terms of intuitive understanding of "spontaneous concepts" through students' performance in the actual game levels and (b) in terms of formal understanding of "instructed concepts" through items from the Force Concept Inventory (FCI) (Hestenes, Wells, & Swackhamer, 1992; Jackson, 2007). In-game performance is measured via data recorded as students employ concepts of velocity, force, and gravity to spheres of varying mass through a series of obstacle courses. We are also utilizing visualization tools to map connections between students' performance and choices in the game (intuitive concepts) with the formal academic assessments (instructed concepts).




19. While you and your friend are running, your science teacher takes measurements. Later he makes this drawing. The little stick figures show where both of you are (your positions) at every second of time. You're both running to the right.

Are you and your friend ever running at the same speed?
(A) No.
(B) Yes, at the 2nd second of time (that is, at the 2nd stick figures).
(C) Yes, at the 5th second of time (that is, at the 5th stick figures).
(D) Yes, at the 2nd and 5th seconds of time.
(E) Yes, at some time between the 3rd and 4th seconds.

Data and Results

The first SURGE study took place in summer 2009. We analyzed 24 undergraduate and graduate students playing SURGE. A paired-samples t-test was performed on the pre/post items and revealed a significant gain from pre to post ($p = .037$). One of the largest gains on an individual item was the one about vector addition. The second SURGE study involved 180 eighth grade students in Taiwan that showed significant gains in 3 test items dealing with Newton's First Law. The gains observed are not dependent on gaming experience and apply to both genders. The items in which gains were observed are those most closely aligned with the experience of controlling the player-object in SURGE. These items deal with things in SURGE players *do*, rather than *see*. The third SURGE study focused on the complexity of formal physics representations to optimize student learning about the physics concepts and representations. The study involved 138 undergraduates enrolled in an introductory calculus-based physics course at a large university. Students in "full" condition (components and resultant velocity vector) did better on vector addition problems (76.7% versus 69.5%), and the post-test (average gain of 11.0% versus 6.8%) than those in "simplified" condition (only resultant velocity vector).

Significance

The results of these first studies suggest that the sequence and structure of the models and representations designed in the SURGE game are effective in changing how students think about the formal instructed concepts in a manner that transfers to certain items from the Force Concept Inventory, but care must be taken to ensure that the ideas that students take away from the game are the ones intended by the designers. In post-gameplay interviews, students remark that the game helps them understand how to improve their answers on the posttest even though they weren't consciously thinking about their learning while they were playing the game. Ongoing work will focus on the balance of guidance and freedom in the gameplay mechanics, the structuring of mechanics to focus students on key concepts, as well as on the nature of representations that best support learning in a gaming context.

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