Was that CT? Assessing Computational Thinking Patterns through Video-Based Prompts

Abstract

The purpose of this study was to evaluate student understanding and application of computational thinking patterns to novel situations. Over 500 students, who had just designed and programmed a Frogger-style game using the AgentSheets platform, responded to a newly developed video-prompt survey instrument administered in the Fall 2010 semester. The students watched video clips and were asked if and how the content of the video was related to the computer game they had just created. Open-ended responses collected from the survey were analyzed and coded for six pre-defined computational thinking patterns. The percent match between student responses and expert responses varied by question, ranging from approximately 35% to 75%. Utilizing alternate definitions of transfer, and the principles of grounded theory, new computational thinking patterns emerged from the student responses. These methods will be utilized in subsequent analysis of data collected from students after they have designed and created other games and STEM simulations. The newly emerging patterns will inform further research into computational thinking. (Contains 3 charts and 4 tables)

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The concept of "Computational Thinking" is getting a lot of attention. Many have attempted to define it, some consider it as fundamental a skill as the 3 R's in education, others wonder if this is the right direction for computer science to be going at all. A Center for Computational Thinking at Carnegie Melon has been created to implement and research computational thinking in education.

The term Computational Thinking was coined by Jeannette Wing and later defined as:

> [T]he thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent [CunySnyderWing10] (Wing, 2010, p. 1)

Others' definitions of Computational Thinking (CT) include: "the ability to interpret the world as algorithmically controlled conversions of inputs to outputs" (Denning, 2009, p. 30), "integrating the power of human thinking with the capabilities of computers" (Phillips, 2007, p. 8), and thinking patterns that originate in computer science but have much wider applications "as they involve systematically and efficiently processing information and tasks, with or without a computer" (Allan et al., 2010). Still others have intentionally avoided the creation of another version of the definition and write "we are less interested in creating a new definition of what computational thinking is (or is not) and are mostly concerned with the pragmatics of computational thinking" (Repenning, Webb, & Ioannidou, 2010, p. 1).

Intense focus on CT leads one to question the importance of the concept. Why has this relatively new idea taken such a strong hold on the interests of computer science education? Cooper, Perez & Rainey (2010) discuss computational thinking as being defined as the "set of computer science skills essential to virtually every person in a technological society" (p. 27). Wing (2010) outlines the benefits of computational thinking, which she calls "the new literacy of the 21st century" (p.3). The benefits include, among others, the ability to determine the components of a problem that are compatible with available computational tools and techniques, and the ability to recognize opportunities to use computation in new ways (Wing, 2010, p. 3). If it is true that all students must be technologically literate to compete and succeed in the 21st century world, then it is imperative that we begin to unpack what these skills are, and determine how we will teach them.

There is a real need to move beyond definitions and into operationalizing (LeCompte & Schensul, 1999, p. 153) computational thinking so that it is understandable, observable and measureable. Basawapatna et al. echo this desire for an operationalized construct by stating,

> [T]he definition of Computational Thinking at the present time is abstract at best … it is essential [that] we concretely define what exactly we expect students to learn. In other words, for Computational Thinking to become a notion that is actionable, teachers require more than just abstract definitions of what computational thinking is or is not (Basawapatna, Koh, Repenning, Webb, & Marshall, 2011)

In an effort to concretely define what skills students will be working to master, Computational Thinking Patterns have been defined (Basawapatna et al., 2010). Several of the patterns are concisely defined below. For more complete definitions and other patterns see Basawapatna et al. (2011) and Basawapatna, Koh, & Repenning (2010).

Collision: This pattern occurs when two or more objects collide. In real life, bumper cars crash into each other. In a virus-spread simulation, an agent with the virus bumps into an agent who is not sick, which may result in the "well" agent catching the virus.

Transportation: This pattern occurs when one agent is carried by another agent. In real life, a mother carrying a child is an example of transportation. In a science simulation, insects transport food back to the nest.

Generation/Absorption: Generation is said to occur when new agents are created by other existing agents and happens in real life and in science simulations when animals breed and create new animals. Absorption occurs when one agent deletes another; in real life this happens when one animal eats another.

Diffusion: For this pattern, an agent has a high level of "scent" and this gradually diminishes further away from this agent. In real life, perfume is strongest near the person who is wearing it and further away the scent is more subtle. In a science simulation, diffusion can be used to indicate where the nest is for insects foraging for food. Diffusion is often used in conjunction with the **Hill Climbing** pattern where agents actively seek the highest "scent" value.

The following patterns were not defined in Basawapatna, Koh, & Repenning (2010) but have emerged through the process of data collection and recursive analysis using the principles of grounded theory (Glaser & Strauss, 1967; LeCompte & Schensul, 1999). The emergence of these patterns will also be discussed in the results section of this paper in the context of transfer.

Movement: The movement of an agent can be directional, random or cursor controlled depending upon the needs of the game or simulation. Directional movement is used for trucks going across the screen on roads; random movement is utilized in a contagion spread simulation, and cursor controlled movement is used for main character agents in many applications.

Students took specific contexts and put them in a more general form. This occurred in two ways: Strategy and Design.

*****Strategy*** In *strategy*, students considered the general rules of games; to get to their goal, winning, avoiding enemies.

*****Design*** In *design*, students thought along the lines of how to create the game on the platform they were using (in this case AgentSheets). Specific actions or conditions were listed and students gave specific agents they would make or behaviors they would program. Students also discussed the importance of creativity and freedom to make whatever you wanted in the design process.

Some STEM simulations may require patterns beyond those defined in the context of game design. Below are other patterns possible in STEM simulations:

Transformation: When the depiction of an agent changes as a result of some property of the simulation, transformation has occurred. In real life this is seen when an animal is injured in fight with another. The "depiction" of the animal would now contain the injury such as a cut or bleeding.

Proximity: This pattern emerges when the physical closeness of one agent to another agent is a prerequisite for some portion of the simulation to occur. For example, for forest fire to spread, the burning tree must be physically close to other trees. This is often used with another emerging pattern of ****Percent Chance***. Even when in close physical proximity, not all trees burn. In other words, there is a probability less than 1 that the agent will catch fire.

Teaching Computational Thinking Skills

Because of student interest in and familiarity with computer games, games are often used to teach programming to those new to programming. Likewise, game design can be used to teach computational thinking patterns (CTPs). **Table 1** lists games and the CTPs used in creating the games. While many feel that game design is a motivating way to begin teaching programming and CTPs, others question the use of instructional time for computer gaming. This seems particularly true in public K-12 education. In a climate of high-stakes standardized assessment, K-12 teachers and administrators are leery of curriculum that does not specifically address the standards of a tested area. In one example given by Repenning et al. (2010), after seeing students create a game using AgentSheets software, one teacher asked, "Now that you can make Space Invaders can you build a science simulation?" (p. 4). Basawapatna et al. (2011) also highlight this requirement when discussing the use of game design for educational purposes, "[T]he student should be able to use their programming knowledge to solve real world problems. The ability to create scientific simulations should be an important benefit of thinking computationally and an indication of STEM proficiency " (p. 1). Enabling transfer of skills to science simulations or mathematical models is listed as one of the three essential characteristics of game design when used for educational purposes (Basawapatna et al., 2011). To indicate the intent of transfer, **Table 1** also includes science simulations and their associated CTPs.

Table 1 Games/ Simulations and corresponding Computational Thinking Patterns (adapted from Basawapatna, Koh, & Repenning, 2010)

Games/ Simulations	Computational Thinking Patterns
Frogger	Generation, Absorption, Collision, Transportation, Movement*, Strategy*, Design*
Pac-Man	Absorption, Collision, Diffusion, Hill Climbing, Movement*
Sims	Multiple Diffusions, Hill Climbing
Contagion Spread Simulation	Random Movement*, Transformation*, Proximity*, Percent Chance*
Forest Fire Simulation	Transformation*, Proximity*, Percent Chance*

* New patterns emerging from data collected.

Measuring transfer as evidence of computational thinking skills mastery

Transfer can be thought of as the "ability to extend what has been learned in one context to new contexts" (National Research Council, 2000, p. 51). Measures of transfer often show different results than those that measure only recall. Many believe that evidence of transfer demonstrates a deeper understanding of a construct. This then highlights differences in the effectiveness of instructional practices. The National Research Council writes, "Instructional differences become more apparent when evaluated from the perspective of how well the learning transfers to new problems and settings" (National Research Council, 2000, p. 77). When teaching students computational thinking skills, evidence of transfer to focus areas in K-12 education (often math, literacy and science) is of importance to the use and sustainability of the curriculum. We have developed a tool to help identify transfer of understanding of computational thinking patterns: the CTP Video-Prompt Survey.

Objectives

The CTP Video-Prompt Survey is an on-line assessment tool used in our research to assess student understanding of computational thinking patterns (CTPs). This tool utilizes video-based prompts to evaluate degree of transfer of understanding of CTPs to real-world situations. This paper discusses this tool in depth and the results obtained from over 500 students taking the survey in the Fall 2010 semester. Data presented here is for the Frogger game only. There was much more data collected for other games and simulations. These results will be the subject of subsequent analysis and publication.

Theoretical Framework

We conducted our research through the lens of constructionism as defined by Michael Crotty (1998), "…the view that all knowledge… is contingent upon human practices, being constructed in and out of interaction between human beings and their world, and developed and transmitted within an essentially social context" (p. 42). Under the larger umbrella of constructionism, activity theory informs our work as we consider mediation by tools and signs within the collective activity system (Engeström, 1999). The CTP Video-Prompt Survey provides feedback to both teachers and students about real-world applications and individual understandings of CTPs in the context of the classroom.

Methods

Data were collected from over 500 middle school students who took the CTP Video-Prompt Survey in the Fall 2010 semester. This quiz utilizes video clips as prompts that demonstrate instances of a modeling behavior and interaction in settings beyond the classroom. For example, to assess understanding of the interactive CTPs of "collision" and "transport," participants viewed a video of an eagle "colliding" with a fish in the water and "transporting" somewhere assumedly to "absorb" his dinner!

Students took the quiz on computers at the end of the AgentSheets unit. Some students had created only a Frogger type game, while others had created additional games such as Pac-Man or STEM simulations such as a virus spread simulation. Although most students included in this study were in technology classes and did the AgentSheets unit as part of their coursework, many of the students who took the CTP Video-Prompt Survey were using AgentSheets as a part of a statistics unit in a mathematics class. In this case, one of the primary purposes of the programming skills developed was to program and use STEM simulations for data collection and analysis. The skills must be transferable to other applications beyond game design and creation.

Many students were unable to complete the survey in the Fall 2010 semester often due to time constraints and/or technology issues. The survey was originally designed using imbedded YouTube videos as question prompts. As we discovered, YouTube is blocked from student use by many schools and districts. We then created a QuickTime version of the survey in addition to the YouTube version. For some districts this did not completely solve the issues, as the QuickTime software on many of the school's machines was either missing or outdated. To remedy this, some teachers had to get their technology coordinator to update the QuickTime software on the school's computers as the teacher often does not have the clearance needed to add or update software. Some were unable to get this done in time to correspond with the end of the unit. Many of these teachers are doing a unit in the Spring 2011 semester and will hopefully have the computers updated and ready to implement the survey.

A pilot version of the CTP Video-Prompt Survey was also given to teachers and community college students during the 2010 Scalable Game Design Summer Institute. This version also utilized video clips as prompts that demonstrated instances of a modeling behavior and interaction in settings beyond the classroom. Though the patterns modeled by the videos were the same, most of the videos used for the pilot survey were different (for example the video for *collision* showed people sledding down a hill and hitting a bystander). There was one video that both surveys had in common however. The results will focus on this video when we analyze teacher, community college and middle school student responses.

Data Sources

The CTP Video-Prompt Survey is the source of data discussed in this paper. As a part of the same research project participants were also asked to complete pre and post motivation surveys and individual interviews were conducted with teachers and select students.

In each of the following questions participants are asked how the video clip is similar to something in the "Frogger" style game they created. If respondents directly named any of the patterns associated with the video, or described the pattern in other words with the same meaning their response was counted in that category. More than one pattern may be listed for each question. Therefore, there were more responses than the number of participants.

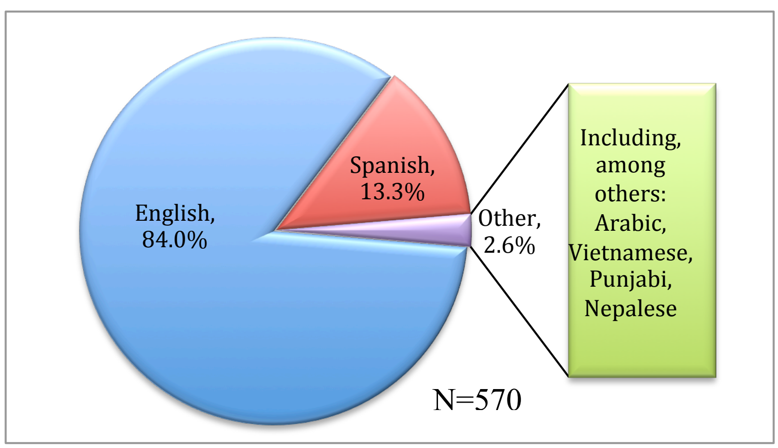
Question 1 shows a flying eagle catching a fish from a lake. This is an example of the *collision* and *transportation* and perhaps even *absorb* if one projects what is likely to happen to the fish in the near future.

Question 2 is a video of a seemingly endless marching band coming out of tunnel. This can be interpreted as *generation* of new agents from an existing agent (the tunnel).

Question 3 is a video of two Sumo wrestlers engaged in a match representing the computational thinking pattern *collision*.

Question 4 shows an advertisement for a "Press-dough" toy that squeezes dough out into different shapes. This is meant to represent *generation* as the shaped dough is created from the dough press.

Chart 1: Respondents' Primary language Spoken at Home

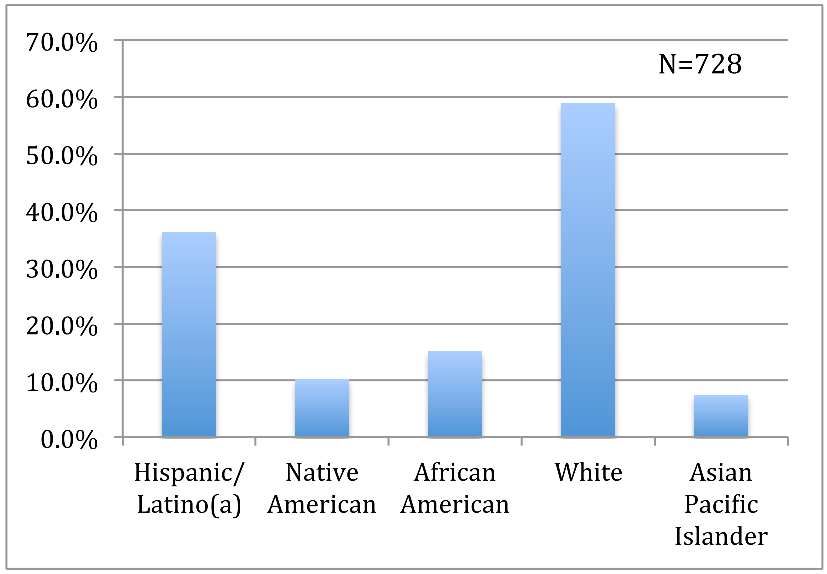


Question 5: is a video clip of a man bowling over a chair. The man throws a ball up in an arc over the chair placed in the alley. The ball lands on the other side of the chair and continues down the lane to make a strike. The ball and pins are involved in a *collision*. Many students also saw this video in terms of the *movement* of the ball.

Sample

The following information is based on the 570 students who completed one or more portions of the CTP Video-Prompt Survey. For over 13% of the respondents, Spanish is the primary language in the home, although very few students chose to take the survey in Spanish. The majority of the respondents (approximately 84%) indicated that English is the primary language spoken in their homes. Other primary home languages were listed by approximately 3% of the respondents and included Arabic, Vietnamese, Punjabi and Nepalese**.** (See **Chart 1**.)

Chart 2: Respondents' Races/Ethnicities



The racial/ethnic mix of the group was diverse as well (See **Chart 2**). Respondents were asked to check "as many as apply" so there are more responses than the number of students (570 total). While the majority of the respondents (approximately 60%) indicated *White* as part or all of their race/ethnicity, approximately 36% of the respondents identified *Hispanic* or *Latino/Latina* (which were separate categories on the survey but are combined in the chart below). Another approximately 10% of the respondents identified as *Native American*, 15% as *African American* and 7% as *Asian Pacific Islander*.

Table 2: Respondents by grade level

Grade	Percent	Number
4th	0.4%	2
5th	2.3%	13
6th	31.8%	181
7th	26.3%	150
8th	35.4%	202
9th	0.2%	1
10th	3.7%	21

N=570

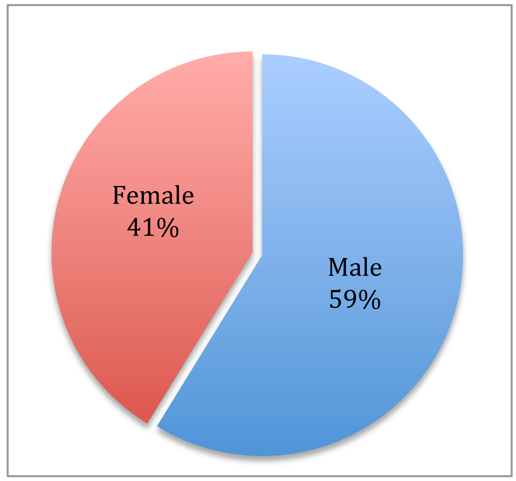
As shown in **Table 2**, the majority of students (93.5%) were fairly evenly divided between 6th, 7th and 8th grades (ages 11-13 years old). There was one 9th /10th grade class that participated (22 students) and fifteen 4th and 5th grade students who completed the survey.

There were more male than female respondents (see **Chart 3**), but 41.2% female participation is quite high compared with many other computer-based activities. This is especially true if the classes are held in after-school computer club environments or are electives during the school day (AAUW Educational Foundation, 2000; Ashcraft, Blithe, & National Center for Women & Information Technology (NCWIT), 2010; Jenson & de Castell, 2010).

Results by Question

As **Table 3** shows, the majority of students, 84% on average, indicated seeing similarities between the video clips and the "Frogger" style game they had created and programmed. The student categorization of these similarities was often one of the defined CTPs. General game play "strategies" such as winning, trying to get the goal, and avoiding enemies were mentioned frequently as well. Respondents also discussed program "design", discussing specific agents they would create or behaviors they would program, and the importance of creativity in program design. Other respondents indicated that the video clips and the game have "common agents" like animals, water or grass.

Chart 3: Respondents' Genders



Several members of the research team decided on the most prominent Computational Thinking Pattern(s) represented by each of the video-prompts in the survey. These patterns are considered the "expert response" to the video-prompts. The percent match between student responses and expert responses varied by question, ranging from approximately 35% to 75%. This wide range of percent matches may indicate that in some cases the videos were too ambiguous. It is also possible that this ambiguity allowed for the emergence of patterns not originally considered by the research team, or that the patterns identified by the researchers were not the same patterns that the students saw when watching the videos. New patterns emerging from the data, such as *movement, strategy* and *design* can be analyzed and utilized in subsequent implementations.

Table 3: Survey results by question

	Some Similarity	**Percent for the Top 3 Responses**			**% Match Expert Response**
Question 1 N=505	85.9%	34.3% (*Collision)	22.8% (*Transport)	17.7% (Strategy)	57.1%
Question 2 N=497	88.3%	54.1% (*Generation)	25.5% (Movement)	8.1% (Strategy)	54.1%
Question 3 N=494	82.2%	75.2% (*Collision)	16.2% (Strategy)	2.7% (Movement)	75.2%
Question 4 N=490	80.9%	52.2% (*Generation)	27.0% (Collision)	8.4% (Design)	52.2%
Question 5 N=489	81.6%	29.3% (Strategy)	27.3% (*Collision)	23.5% (Movement)	34.8% (+ 7.6% *Absorb)

* Expert Response

Question 1:
In Question 1, the video depicts a flying eagle catching a fish, representing the CTPs *collision* and *transport* as the "expert responses". Nearly 86% of the respondents saw some similarity between this video and the "Frogger" style game that they had created using AgentSheets software. More than half (approximately 57%) of the responses matched one or more of the expert responses. A typical response for *collision* in this question was along the lines of "the fish is like frogger and the eagle is a car and frogger got killed by a car" (response from middle school student). An example response for *transport* was "It is similar because when a bird dove to catch the fish it was like a frog jumping on a log, alligator head, turtle, or lily pad" (response from middle school student).
Question 2:
In Question 2, the video shows a marching band coming out of tunnel, which is similar to the *generation* Computational Thinking Pattern. Of all the 5 questions, the highest percentage of students (over 88%) saw some similarity between this video and the "Frogger" style game they created. Again, more than half (approximately 54%) of the respondents' answers matched the expert response. Example responses for *generation* in this question are "It's like when the cars, logs, and turtles come out of tunnels, trees, and bridges" or "trucks generating from tunnels are like the band coming out of the tunnel" (responses from middle school students).

As previously mentioned, a pilot version of the CTP Video-Prompt Survey given to teachers and community college (CC) students who attended the 2010 Scalable Game Design Summer Institute. The institute is a two-week training on using AgentSheets and the Scalable Game Design curriculum in the classroom. During the training, teachers and CC students (who provide classroom support during the school year) created several games including "Frogger", "Pac-Man", "Space Invaders" and "Sims" style games, as well as several STEM simulations such as insects foraging and virus spread models.

The same video prompt of the marching band was used in the survey given to teachers and CC students as was used for middle school students. In contrast, 22 of the 26 teachers' responses (approximately 85%) and 14 of the 16 community college students' responses (approximately 88%) matched the expert response of *generation.*

Table 4. Identification of CTPs in Video Clips

Post-Institute Computational Thinking Quiz		
CT Pattern	Teachers (n=26)	CC Students (n=16)
Collision (1)	21 (81%)	16 (100%)
Collision (2)	20 (77%)	15 (94%)
Generation	22 (85%)	14 (88%)
Absorption	25 (96%)	16 (100%)
Diffusion	24 (92%)	15 (94%)
Diffusion/ Hill-climbing	25 (96%)	16 (100%)
Movement	10 (38%)	6 (38%)
	(% Match with Expert Response)	

Table 4 shows the percent match rate by pattern for the teachers and CC students. One possible reason for the discrepancy in percent match with expert response (about 54% for middle school students versus over 85% for teachers and CC students) is that the videos chosen for students were intentionally more ambiguous to elicit a wider range of responses. Further research exploring the reasons for the discrepancy is indicated.

Question 3:
In Question 3, the video depicts two Sumo wrestlers engaging in match, representing the CTP *collision* as the "expert response". Over 82% of the respondents saw some similarity between this video and their "Frogger" style game. This video also had the largest percent match with expert response at over 75%. Example response for *collision* in this question are "when the 2 people hit it is like when the truck hits the frog" and "The two sumo wrestlers colliding in the fight are like the truck and frog colliding in the game" (responses from middle school students).

Question 4:

In Question 4, the video shows a Press-dough toy squishing out dough into various shapes (see photo to right). This is similar to the *generation* Computational Thinking Pattern. Of the 5 questions in the survey about the "Frogger" style game, the lowest percentage of students (approximately 81%) saw some similarity between this video and the game they created. Still, more than half (approximately 52%) of the respondents' answers matched the expert response. Example responses for *generation* in this question are "the dough squishing out of the holes is like the trucks, turtles, and logs coming out of the tunnels" and "There is stuff coming from a tunnel or passage" (responses from middle school students). Other students identified this video as demonstrating *collision* and likening it to when the frog gets hit by the truck, "The playdough is like the frog being smushed by a car" and "Like when the frog is trying to cross the raod [*sic*] the truck runs over him and kills him splat in 12 different designs" (responses from middle school students).

Question 5:
In Question 5, the video depicts a man bowling over a chair, representing the CTPs *collision* and *absorption* as the "expert responses". Approximately 82% of the respondents saw some similarity between this video and their "Frogger" style game. However, this video had the lowest percent match with expert response by far at approximately 35%. Responses were fairly evenly split between *strategy*, *collision* and *movement* (see Table 2). An example response for collision in this question is "The ball moves like the frog does and collides with the pins like the trucks collide with the frog" (response from middle school student). The largest number of respondents talked about *strategy* aspects of similarity between their game and the video with responses like, "Its like hopping on a turtle and winning the game", "They have to ignore the enemie [*sic*] and go for the win" or "this video is like frogger because the chair is like the trucks and the bowling ball is like frogger so frogger has to evade the trucks to live or in this case the chair" (responses from middle school students). There were also a good number of responses that related this video to some type of movement; "this is like the frog jumping over the water" and "It jumps the chair like a river" (responses from middle school students).

Originally we were considering transfer in a traditional sense only by matching student responses against researcher-defined CTPs. However, when the video prompts were less obviously depicting one particular pattern, the student responses became more varied and creative new computational thinking patterns began emerging from data collected. It is important to note that these patterns are less obvious *to students*, not necessarily researchers. In Question 5 for example, bowling clearly indicated *collision* for us and the ball is *absorbed* into the tunnel at the end and *regenerated* to use again. However, for students, these patterns were not as clear.

Alternate actor-orientation views of transfer allow for new meaning to come forth from the perspective of the respondent.

When using actor-oriented views of transfer, transfer is seen as "the generalization of learning" rather than the "formation of particular, highly valued generalizations" often used in classical transfer approaches (Lobato, 2008, p. 171). In this case, students' generalization of learning to *strategies, movement* and *design* may be evidence of transfer as much as student identification of the "particular, highly valued" pre-defined *collision*, *absorption* and *generation*. From this perspective, we were able to identify additional CTPs that can be included in future research, instruction and assessment.

Significance

The Computational Thinking Patterns Video-Prompt Survey aims to assess skills that students can put to use in a variety of situations, including STEM simulations and areas beyond formal learning environments. By utilizing video prompts of real-life events and relating these to CTPs used in computing, we can assess what students know about these patterns and the extent to which this knowledge can be used to model realistic situations.

As an estimated 1000 additional students will respond to the CTP Video-Prompt Survey during the current Spring 2011 semester, future research will involve recursive analysis of the patterns emerging from student responses. These responses will give us more information on the usefulness of the CTPs, especially in the area of STEM simulations.

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