*Jl. of Interactive Learning Research (2008)* **19***(2)*, 185-224

# Why Students Engage in "Gaming the System" Behavior in Interactive Learning Environments

RYAN BAKER
*Carnegie Mellon University, USA*
ryan@educationaldatamining.org

JASON WALONOSKI
*The MITRE Corporation, USA*
jwalonoski@mitre.org

NEIL HEFFERNAN
*Worcester Polytechnic Institute, USA*
nth@wpi.edu

IDO ROLL, ALBERT CORBETT, AND KENNETH KOEDINGER
*Carnegie Mellon University, USA*
idoroll@cmu.edu
corbett@cmu.edu
koedinger@cmu.edu

In recent years there has been increasing interest in the phenomena of "gaming the system," where a learner attempts to succeed in an educational environment by exploiting properties of the system's help and feedback rather than by attempting to learn the material. Developing environments that respond constructively and effectively to gaming depends upon understanding why students choose to game. In this article, we present three studies, conducted with two different learning environments, which present evidence on which student behaviors, motivations, and emotions are associated with the choice to game the system. We also present a fourth study to determine how teachers' perspectives on gaming behavior are similar to, and different from, researchers' perspectives and the data from our studies. We discuss what motivational and attitudinal patterns are associated with gaming behavior across studies, and what the implications are for the design of interactive learning environment.

In recent years, there has been increasing evidence that students choose to use interactive learning environments in a surprising variety of ways (Wood & Wood, 1999; Aleven, McLaren, Roll, & Koedinger, 2004; Baker, Corbett, Koedinger, Wagner, et al., 2004; Mostow et al., 2002; Arroyo & Woolf, 2005; Stevens & Soller, 2005), and that some choices are associated with poorer learning (Baker, Corbett, Koedinger, Wagner, et al., 2004; Beck, 2005; Aleven, McLaren, Roll, & Koedinger, 2006). In particular, one category of behavior, termed "gaming the system," has been repeatedly found to be associated with poorer learning (Baker, Corbett, Koedinger, Wagner, et al., 2004; Baker, Roll, Corbett, & Koedinger, 2005; Beck; Walonoski & Heffernan, 2006a). Baker (2005) defined gaming the system as "attempting to succeed in an educational environment by exploiting properties of the system rather than by learning the material and trying to use that knowledge to answer correctly."

Gaming behaviors have been observed in a variety of types of learning environments, from educational games (Klawe, 1998; Magnussen & Misfeldt, 2004) to online course discussion forums (Cheng & Vassileva, 2005), and have been repeatedly documented in one type of interactive learning environment, intelligent tutoring systems (Aleven, 2001; Baker, Corbett, Koedinger, & Wagner, et al., 2004; Beck, 2005; Mostow et al., 2002; Murray & vanLehn, 2005; Schofield, 1995; Wood & Wood, 1999). Across the systems studied, a reasonably substantial minority of students (10-40%) appear to engage in some variety of gaming behavior, at least some of the time.

Within Cognitive Tutors and ASSISTments, the two types of intelligent tutoring systems we investigate in this article, gaming the system consists of the following behaviors:

1. quickly and repeatedly asking for help until the tutor gives the student the correct answer (Wood & Wood, 1999; Aleven, 2001); and
2. inputting a sequence of answer attempts quickly and systematically. For instance, systematically guessing numbers in order (1,2,3,4…) or clicking every checkbox within a set of multiple-choice answers, until the tutor identifies a correct answer and allows the student to advance.

Other examples of gaming the system include choosing to work on material which the student has already memorized (personal communication, Jack Mostow), restarting problems when a tutoring system only saves at the end of each problem, and intentionally posting irrelevant material to online course discussion (Cheng & Vassileva, 2005).

Recent work to model this behavior has resulted in systems, which can effectively detect gaming behaviors in a variety of intelligent tutoring systems (Baker, Corbett, & Koedinger, 2004; Beck, 2005; Baker, Corbett, Koedinger, & Roll, 2006; Walonoski & Heffernan, 2006a; Johns & Woolf, 2006; Beal, Qu, & Lee, 2006), using a considerable variety of modeling frameworks and approaches. The ability to effectively detect gaming has spurred the development of systems that attempt to respond to gaming, when it occurs. Prior to this work, most attempts to remediate gaming consisted of attempting to make it impossible for students to game (Aleven, 2001; Murray & vanLehn, 2005), but it was found that this approach both reduced the usefulness of help features for nongaming students (Baker, Corbett, Koedinger, & Wagner, 2004) and that gaming students discovered new strategies for gaming that worked despite the system redesigns (Murray & vanLehn, 2005). Newer systems have responded to gaming using models that identified exactly when and which students game the system, and by producing visualizations of student gaming that were visible to both the student and their teacher, instant feedback messages that notify the student that they are gaming, and/or supplementary exercises on exactly the material the students have bypassed through gaming. These systems have been successful in reducing the prevalence of gaming behavior (Walonoski & Heffernan, 2006b; Baker, Corbett, Koedinger, Evenson, et al., 2006), and in improving gaming students' learning (Baker, Corbett, Koedinger, Evenson, et al., 2006), over short (approximately week-long) sections of intelligent tutor curricula. However, it does not appear that these systems address the root causes of gaming; instead these systems only alleviate gaming's symptoms. Hence, it seems quite possible that students will over time discover ways to defeat these interventions over time.

To have confidence that a redesign will address the root causes of gaming behavior, rather than briefly alleviating its symptoms, our community needs to understand why students game – both in terms of context (what specific situations students choose to game in), and of student characteristics (what factors differentiate the students who engage in gaming behavior from the majority of students who do not). There is already preliminary evidence about *when* students game, gathered in the process of developing detectors of gaming behavior, showing that students game on steps they personally find difficult. However, knowing that some students game on steps they personally find difficult does not tell us why the majority of students do not.

In this article, we will investigate why some students choose to game while other students choose not to game, using evidence from three studies across two different types of interactive learning environments, Cognitive Tutors (Anderson, Corbett, Koedinger, & Pelletier, 1995) and ASSISTments (Razzaq et al., 2007). By investigating this question across multiple systems with independent methods of detecting gaming, we can have some confidence that our findings will generalize beyond just a single type of learning environment.

This article is organized as follows: first, we will discuss a set of hypotheses for why some students game, drawn from the literature on gaming, motivation, and related classroom behaviors. Next, we will present evidence on teachers' perspectives about why students game. Then we will discuss three questionnaire studies where we gave questionnaire items to students (relevant to the hypotheses) and correlated students' responses to their frequency of gaming. Next, we consider how each of the hypotheses is confirmed or disconfirmed by the data from the students' responses, and how the results from our studies correspond to the teachers' predictions. Finally, we discuss the psychological and design implications of our results.

## Systems Studied

Within this article, we will consider data on the student characteristics associated with gaming the system from two different interactive learning environments: Cognitive Tutors (shown in Figure 1) and ASSISTments (shown in Figure 2). Both environments can broadly be characterized as intelligent tutoring systems or coached practice, but differ in many ways at a finer level of detail. Within each type of learning environment, each student works individually with the computer software to complete mathematics problems. Problems in each Cognitive Tutor curriculum are designed to map to specific parts of state-mandated mathematics curricula, and are organized into lessons by curricular themes. Problems in the ASSISTments system are designed to map to the problems found in a state mathematics exam, the Massachusetts Comprehensive Assessment System (Razzaq et al., 2007), are explicitly modeled on problems from exams in previous years, and are also grouped into curriculums by mathematical topic.

A Cognitive Tutor breaks down each mathematics problem into the steps used to solve it, making the student's thinking visible, whereas ASSISTments provide a complete problem, and break down the problem into steps only if the student makes errors or has difficulties.

In both environments, as a student works through a problem, a running cognitive model assesses whether the student's answers map to correct understanding or to a known misconception (Anderson et al., 1995), and errors are flagged. In addition, each system offers further learning support. Cognitive Tutors give tailored feedback when a student's answer is indicative of a known misconception. The ASSISTments system responds to a wrong answer with both targeted feedback and supplementary questions that break down the problem-solving exercise into the required component skills.

Beyond instant feedback, both systems offer multi-level on demand hints to students. When a student requests a hint (by clicking a button), the software first gives a conceptual hint. The student can then request further hints, which become more and more specific until the student is given the answer (as in Figure 1). The hints are context-sensitive and tailored to the exact problem step the student is working on.

Within a Cognitive Tutor, as the student works through a set of problems, the system uses Bayesian Knowledge Tracing (Corbett & Anderson, 1995) to determine how well the student is learning the component skills in the cognitive model, calculating the probability that the student knows each skill based on that

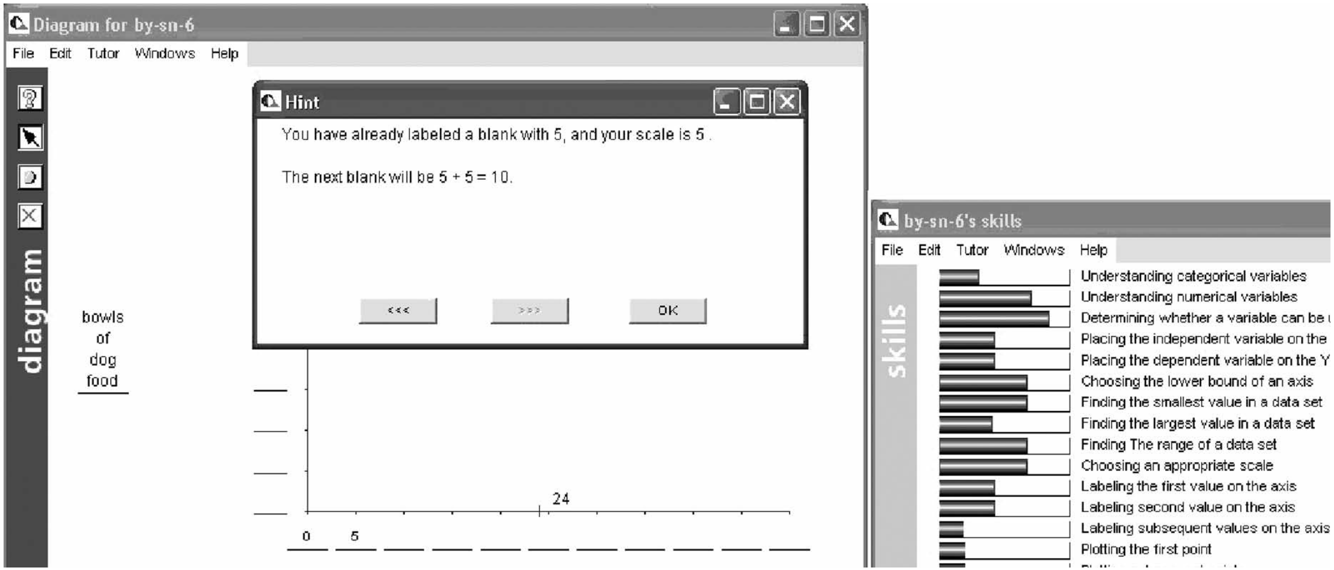


**Figure 1.** A student reading the last message of a multi-level hint in a Cognitive Tutor lesson on scatterplots: the student labels the graph's axes and plots points in the left window; the tutor's estimates of the student's skills are shown in the right window; the hint window (superimposed on the left window) enables the tutor to give the student feedback

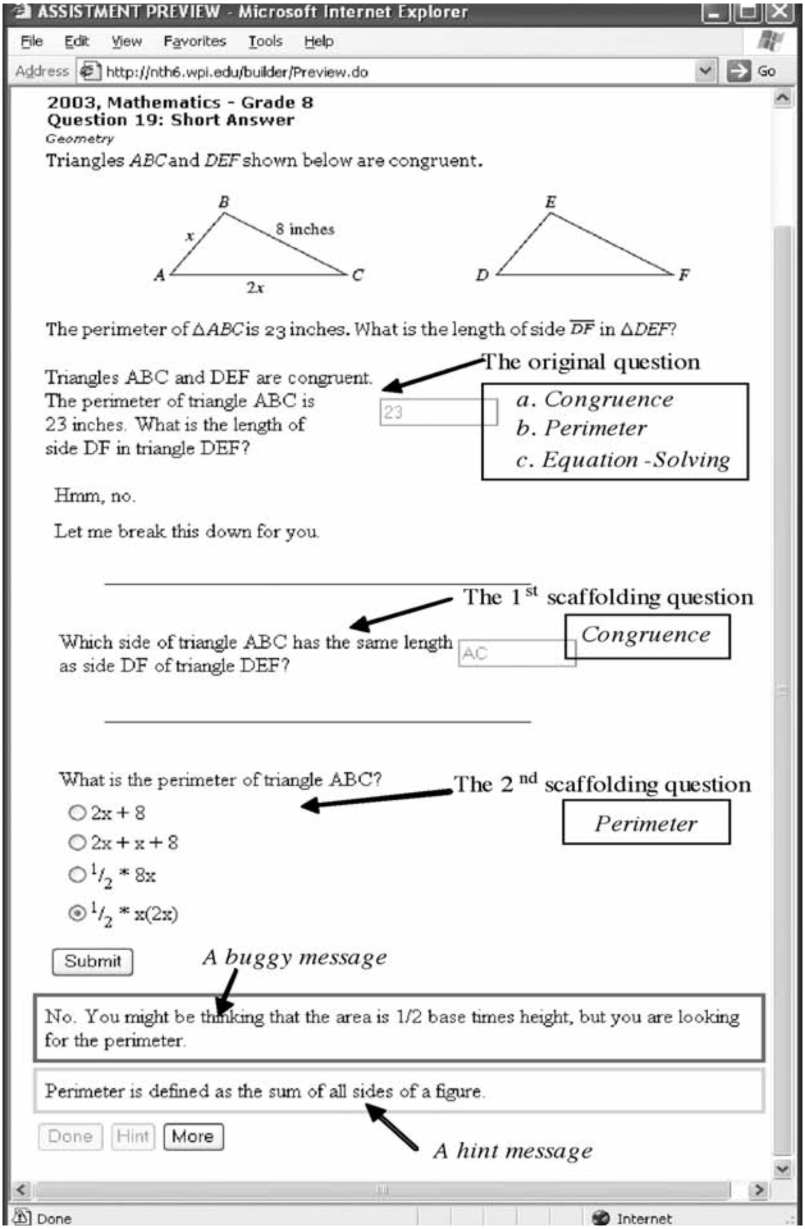


**Figure 2.** An ASSISTment where a student made an error on the question, completed the 1st scaffolding question, and is in the middle of trying to answer the 2nd question

student's history of responses within the tutor. Using these estimates of student knowledge, the tutoring system gives each student problems, which are relevant to the skills which he or she needs to learn. The ASSISTments system does not have similar functionality, and instead selects problems from predefined sets.

Both Cognitive Tutors and the ASSISTments system are used in combination with regular classroom instruction; students use the Cognitive Tutor or ASSISTments system once or twice a week as part of a regular mathematics course, and have classroom lecture or group work on the other days. Both systems have been validated to result in positive student learning outcomes. Cognitive Tutor curricula have been validated to be highly effective at helping students learn mathematics, leading not only to better scores on the Math SAT standardized test than traditional curricula (Koedinger, Anderson, Hadley, & Mark, 1997), but also to a higher percentage of students choosing to take upper-level mathematics courses (Carnegie Learning, 2002). In recent years, Cognitive Tutor mathematics curricula have come into use in an increasing percentage of U.S. high schools – about 6% of U.S. high schools as of the 2005-2006 school year. The ASSISTments system is considerably newer, and has thus been less thoroughly studied, but its use has also been shown to result in significantly better learning (Razzaq et al., 2007). In 2006-2007, 3,000 students are using ASSISTments as part of their math class.

## HYPOTHESES

To determine what factors might lead students to game the system, we conducted a thorough review of the relevant literature on gaming-like behavior in both traditional classrooms and in online settings. In general, the existing literature had considerably more hypothesis than concrete data about why students engage in gaming-like behavior, though notable exceptions to this trend do exist (Arbreton, 1998). We also reviewed literature on the range of attitudes, beliefs, and motivations students show towards technology and school, and the range of attitudes and beliefs that cause people to behave in resistant and subversive ways outside of educational settings, as will be discussed in the following sections. Finally, we engaged in both structured and nonstructured brainstorming (Kelley & Littman, 2001) with school teachers and colleagues in a variety of scientific areas, including educational technology researchers, educational psychologists, behavior modification researchers, and interaction designers.

It is important to note that not all of this literature review and brainstorming took place at once; instead, it took place across a span of three years. Some hypothesis formation took place before any of the three studies were conducted, but hypothesis formation continued in between each of the studies reported in this article. Through this process of discussion, brainstorming, and literature review, we have come to 13 hypotheses for why students game. It is important to note that this is by no means an exhaustive list of the reasons students may elect to game the system. A virtually limitless set of hypotheses may be generated; we claim only that the set presented is reasonably well-justified by either prior research or practitioners' and researchers' past informal experience.

For presentation purposes we categorize our 13 hypotheses into groups. These categories are meant only to group hypotheses together that have some relation to one another, to facilitate understanding, not to make any broader theoretical claims. Within this article, the important unit of analysis is the hypotheses themselves and their corresponding results, not the categories. The five categories of hypotheses are: hypotheses relating gaming to students' goals (H1, H2), hypotheses relating gaming to students' attitudes (H3-H5), hypotheses relating gaming to students' beliefs (H6-H9), hypotheses relating gaming to students' broader responses to educational situations (H10, H11), and hypotheses relating gaming to students' emotions (H12, H13).

### Hypothesis H1: Performance Goals

Our first hypothesis, and the most commonly proposed hypothesis for why students game, prior to the research presented here (Baker, Corbett, Koedinger, & Wagner, et al., 2004; Martinez-Miron, du Boulay, & Luckin, 2004), is that students game the system because they have performance goals rather than learning goals (the distinction between performance goals and learning goals is discussed in detail in Dweck, 2000). In this case, a student using educational software wants to "succeed" in the environment, by completing all of the problems, more than he or she wants to learn the material contained in those problems. To complete more problems, the student engages in gaming behaviors.

Some evidence on student behavior in traditional classrooms supports this hypothesis. Specifically, some students in traditional classrooms engage in a behavior termed "executive help-seeking." In this behavior, a student starting work on a new problem requests help from their teacher or a teacher's aide immediately, before attempting to solve the problem on their own. Arbreton (1998) found that executive help-seeking was significantly correlated with performance goals, as measured through questionnaire items.

### Hypothesis H2: Desire For More Control

Our second hypothesis is that students game the system out of a desire for more control over their learning experience. In this case, a student using a fairly constrained learning environment, such as Cognitive Tutors or ASSISTments, feels that they do not have control over their learning experience, and games the system to regain control over their learning experience (for example, avoiding problems the student does not wish to solve).

This hypothesis was formed based on informal comments made by students in previous studies, and is potentially congruent with prior studies that have found that giving students greater control within constrained learning environments, even over relatively minor aspects of their learning experience, can improve student motivation and even increase student learning (Cordova & Lepper, 1996). It is possible that one of the reasons choice improves learning is because it reduces gaming.

### Hypothesis H3: Disliking Mathematics

Our third hypothesis is that students game the system in a learning environment because they dislike the subject matter taught in that learning environment – in the case of the specific systems studied within this article, mathematics. In this hypothesis, a student who dislikes mathematics attempts to make progress without having to engage with the disliked material – by gaming the system. This hypothesis views gaming as a form of effort withdrawal, and is consistent with prior research showing that students generally put more effort into learning material that they find interesting (Schiefele, 1991).

### Hypothesis H4: Disliking Computers

Our fourth hypothesis is that students game the system because they dislike computers. Potentially, a student who dislikes computers might game the system as a means of refusing to work with a computer he or she dislikes, without attracting the teacher's attention. Alternatively, a student who dislikes computers might lack patience for working through problems with a computer (and therefore choose to game the system). In general, if a relationship exists between disliking computers and gaming the system, it may be mediated by some of the beliefs about computers that form hypotheses 8 and 9, or even by lack of self-drive (hypothesis 12).

### Hypothesis H5: Disliking the Learning Environment

Our fifth hypothesis is that students game the system in an interactive learning environment because they dislike that specific learning environment (but not necessarily computers in general). A student might dislike a learning environment for many reasons, from disliking features in the environment's design (see hypothesis 8), to preferring normal classroom work to using that learning environment, to disliking having to put in continual effort (which may be more difficult to avoid in computer tutors than traditional classrooms). Disliking a specific learning environment might lead a student to game the system for many of the same reasons that disliking computers would, and may be mediated by some of the same factors: beliefs about computers (hypotheses 8 and 9), a desire for control (hypothesis 2), or lack of self-drive (hypothesis 12).

### Hypothesis H6: Believing Mathematics is not Important

Our sixth hypothesis is that students game the system in an interactive learning environment because they do not believe that the subject matter (mathematics) taught in that learning environment is important.

This hypothesis is compatible with the prior finding that students put more effort into learning material that they personally find important (Schiefele, 1991). Many students do not consider mathematics to be personally important or valuable to their long-term goals (Pettitt, 1995); such students may game the system as a way of reducing their effort.

### Hypothesis H7: Believing Success in Mathematics is Due to Innate Ability, not Effort

Our seventh hypothesis is that students game the system because they believe that they will not be able to succeed in the tutor whether or not they put in effort. A student may believe this because they believe that some students are good at math and others are bad at math (an entity theory of intelligence – Stipek & Gralinski, 1996; Dweck, 2000), and worries that they themselves are not good at math. Entity theories have been shown to be associated with self-handicapping behaviors (Rhodewalt, 1994; Dweck), suggesting that a student with an entity theory may game the system to avoid the experience of trying to solve the tutor problems appropriately and failing.

### Hypothesis H8: Believing the Tutor is Not Helpful For Learning

Our eighth hypothesis is that students game the system because they believe that the tutor will not help them learn, perhaps due to dissatisfaction with some aspect of the tutor (the design of problems or hint messages, for example). Since the student believes they can not learn from the tutor, they adopt the strategy of gaming the system to complete problems with minimal effort. This hypothesis corresponds to the finding the adoption of software generally is strongly associated with how beneficial the user believes the software will be (Venkatesh & Davis, 2000).

### Hypothesis H9: Believing Computers/the Tutor are Uncaring

Our ninth hypothesis is that students game the system because they believe that the tutor and/or computer does not (or cannot) care if they learn, and thus do not feel motivated to put the same effort into their interactions with the tutor as they would with a human teacher or tutor. This hypothesis is effectively the converse of the hypothesis by Bickmore and Picard (2004), that machines that act in more explicitly caring fashions will improve user motivation and performance. If a more caring computer may improve motivation and performance, it is reasonable to expect that a computer perceived as uncaring may worsen motivation and performance.

### Hypothesis H10: Lack of Educational Self-Drive

Our 10th hypothesis is that students game the system because they lack self-drive, especially for completing tasks, which do not personally motivate them. People vary in their degree of patience for completing tasks, which they find personally uninteresting or unmotivating (Sansone, Wiebe, & Morgan, 1999). Though students generally find Cognitive Tutors motivating (Schofield, 1995), it is likely that many students find working through mathematics problems in computer software unmotivating to at least some degree, or in some situations. Which students persist in working through problems carefully, and which students choose to game the system, may depend on students' general orientation to educational situations.

The construct of self-drive is strongly related to conscientiousness (McCrae & Costa, 1990; Sansone et al., 1999); we use the term self-drive here simply to distinguish lack of self-drive in specific educational settings from the more global construct that conscientiousness is thought to be. In line with that goal, the items used in Tutor Study 2 to assess this construct are drawn from a study skills inventory rather than from a personality inventory.

### Hypothesis H11: Passive-Aggressiveness

Our 11th hypothesis is that gaming the system is a type of passive-aggressive behavior. Passive-aggressive behavior is defined as a "pervasive pattern of negativistic attitudes and passive resistance to demands for adequate performance" (American Psychiatric Association, 1994, pp.634-635), and is associated with behaviors such as procrastination, argumentativeness, obstructive behavior, and pretending to forget obligations (Stone, 1993). Hence, under this hypothesis, a student games the system specifically to resist using the software to learn mathematics (as the teacher requests) without visibly appearing to be resisting.

It is important to note that we are not necessarily saying that students who game the system do so because of personality disorders. However, the overall construct of passive-aggressiveness may relate to a student's decision to game the system.

### Hypothesis H12: Frustration

Our 12th hypothesis is that students game the system when and/or because they feel frustrated by the tutoring software. In this hypothesis, a student feels frustrated because of the difficulty of the mathematics or the challenges of using the tutoring software, and games the system to bypass the frustrating material or interface issue.

Prior research appears to suggest that frustration can lead to lack of persistence in using an interactive system, both within educational software and other types of software – or at least that alleviating frustration significantly improves persistence. A wizard-of-Oz study of affective scaffolding in a reading tutor found that students expressed considerable frustration with errors in the tutor's voice recognition, and addressing that frustration caused students to persist in using the software longer (Aist, Kort, Reilly, Mostow, & Picard, 2002).

### Hypothesis H13: Anxiety

Our 13th, and final, hypothesis is that students game the system because they feel anxious when they use the tutor (perhaps because they find the mathematics difficult or believe other students are performing better in the tutor than they are). Gaming may both enable a student to appear to succeed (by completing problems successfully over time) without risking failure, and provide a student with an excuse for not knowing the material – the student does not know the material because he or she did not try not because the student tried and failed – a behavior known as self-handicapping (Rhodewalt, 1994). Anxiety and self-handicapping behavior have been found to be related to one another in past research (Dweck, 2000).

## TEACHER PERSPECTIVES

Teachers play an essential role in intelligent tutor classrooms (Schofield, 1995). Since teachers observe students using intelligent tutors for considerable periods of time, they may have useful insight as to why students choose to game. We sought to capture teacher perspectives, and compare them to the results found by analyzing students' self-reports. These results should be useful in developing systems that respond to gaming in a way that teachers find valid and appropriate, so that our systems and the teachers will not work at cross-purposes. In this section we report the results of a survey designed to determine why teachers think students game the system.

### Methodology

We surveyed 18 seventh and eighth grade public school teachers who had used ASSISTments in their classes about why they thought students "game the system." Thirteen (13) of the teachers had used the system for over a year.

The teachers were given a definition of gaming in the survey instructions (shown in the Appendix). After reading our definition of gaming behavior, all teachers understood it well enough to answer the survey – none of the teachers reported not understanding what gaming was.

In the survey, we asked the teachers to rank our 13 hypotheses by marking the top three reasons they thought students gamed (with *1*, *2*, or *3*), and marking any hypothesis that they thought was absolutely not responsible for or related to student gaming with an *X*. To avoid biasing our results with the presentation order we grouped our 13 hypotheses into the same five general categories used for presentation in the Hypotheses section, and made five different versions of the survey form, each with a different ordering of the five sections. In addition, a space was provided on the form for teachers to provide other explanations for why students game, to generate new hypotheses. One version of the survey is reproduced in the Appendix.

One potential flaw with our methodology was that the survey was administered by one of the creators of the ASSISTment system (the third author), who was personally known by the teachers. This may have discouraged the respondents from blaming gaming directly on flaws in the ASSISTment system.

### Results

Table 1 shows the study's results. The first row of data shows how many teachers ranked each hypothesis as the most important reason why students game. The second data row shows the number of teachers that ranked each hypothesis as second most likely, and the third data row shows the third-place rankings. The "Sum" column aggregates the total number of votes in favor of each hypothesis. The row called "Disagreements" shows the number of teachers that explicitly stated that a particular hypothesis would not explain why students game.

Three explanations were significantly more popular than the rest: Frustration (H12), Lack of Self-Drive (H10), and Performance Goals (H1). At least half of the 18 teachers listed these three reasons; no other hypothesis was selected by more than five of the teachers. Frustration (H12) was the clear favorite explanation, listed as a top-three explanation by the largest number of teachers, and listed as the most important explanation by the largest number of teachers (9 of the 18 teachers).

Five hypotheses were particularly unpopular: H4 (Disliking Computers), H2 (Desire for Control), H5 (Disliking the Learning Environment), H9 (Believing Computers/the Tutor are Uncaring), and H8 (Believing the Tutor is Not Helpful For Learning). None of these hypotheses had a single vote in favor, and was explicitly rejected by 7 or more of the 18 teachers. From this result, we can conclude that teachers did not think that students' negative attitudes towards computers or the learning environment were central reasons for gaming.

In addition, many open-response comments about gaming seemed to be related to effort avoidance:

- "they are not trying hard,"
- "lack of effort,"
- "do not want to read,"
- "too long to go through the hints,"
- "instant gratification," and
- "some students may game because they lack motivation to learn independently."

**Table 1**
Summary of Teacher Survey Responses: Teachers Were Asked to List Their Three Top Reasons for Gamming and to Disagree With as Many as They Liked

| | Student Characteristics | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Goals | | Attitudes | | | Beliefs | | | | General Approaches | | Emotions | |
| | **H1** | **H2** | **H3** | **H4** | **H5** | **H6** | **H7** | **H8** | **H9** | **H10** | **H11** | **H12** | **H13** |
| First Place | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 5 | 0 | 9 | 0 |
| Second Place | 3 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 2 | 3 | 1 |
| Third Place | 3 | 0 | 2 | 0 | 0 | 1 | 4 | 0 | 0 | 1 | 2 | 0 | 3 |
| **Sum** | **9** | **0** | **4** | **0** | **0** | **1** | **5** | **0** | **0** | **11** | **4** | **12** | **4** |
| **Disagreements** | 2 | 9 | 5 | 11 | 9 | 5 | 1 | 7 | 8 | 0 | 0 | 1 | 4 |

Two other comments focused on students' lack of math background:

- "don't know the math," and
- "I would guess that students who have the most difficulty with the questions game the most. Many of my 7th grade students do not have 7th grade math ability. They give up, due to lack of understanding, assume they cannot learn it and begin guessing/gaming."

Another interesting comment made by multiple teachers was that many students game the system in the classroom on days when they are not using the computer, as in Arbreton (1998).

We conclude that teachers believe that students game the system because they are frustrated, and/or lack the drive to put forth the effort. Teachers also believed that student gamed because they had performance goals.

## QUESTIONNAIRE STUDIES

In three separate studies, questionnaires were given to students, with questions relevant to the 13 hypotheses about gaming. By correlating the incidence of gaming the system (detected using behavior detectors developed separately for each system – those detectors will be described in this section) to student responses on the questionnaires, it is possible to assess to what degree each of the hypotheses appear to be associated with gaming.

The first study conducted on why students game, Cognitive Tutor Study One, was conducted in Spring 2004. Cognitive Tutor Study Two and ASSISTments Study were conducted after Cognitive Tutor Study One had been presented at a conference (Baker et al., 2005), and their designs were influenced by that study's results. Cognitive Tutor Study Two was designed to refine the results in Cognitive Tutor Study One and investigate hypotheses not considered in that study. The ASSISTments Study was intended both to replicate Cognitive Tutor Study One in a different learning environment, and to investigate hypotheses not considered in that study. This section describes the methods for all three studies and the next section reports the results for the three studies.

### Cognitive Tutor Study One

***Study goals.*** The first study on the relationship between student goals, beliefs, and motivations, and the choice to game the system, was designed primarily to investigate hypothesis H1 (performance goals) and hypothesis H13 (anxiety). Hypothesis H1 was the hypothesis most strongly predicted by the literature and the research community (Baker, Corbett, Koedinger, & Wagner, 2004; Martínez-Mirón et al., 2004); hypothesis H13 was the hypothesis most strongly predicted by teachers collaborating with the Cognitive Tutor research group, in informal conversations. Hypotheses H4 (disliking computers) and H5 (disliking the interactive learning environment) were also considered within this study.

***Participants.*** These four hypotheses for why students choose to game the system were studied within the context of six classes at two schools in the Pittsburgh suburbs. All students were in the second semester of a year-long cognitive tutor course for middle school mathematics, in 2004. All students in the study had used Cognitive Tutors multiple times a week for several months. This study took place within a short (two class period) Cognitive Tutor lesson on scatterplot generation and interpretation. Student ages ranged from approximately 12 to 14. One hundred two (102) students completed all stages of the study; 23 other students were removed from analysis due to missing one or more parts of the study.

***Cognitive tutor curriculum.*** In Cognitive Tutor Study One, students were studied as they used a cognitive tutor lesson on scatterplot generation and interpretation (shown in Figure 1), which was known from past research to lead to significantly improved learning. Full detail on this lesson is given in Baker (2005).

***Gaming behavior model.*** The incidence of gaming behavior, for each student, was assessed using a detector of gaming behavior that identifies how often each student is gaming the system. This detector is discussed in detail in Baker (2005); in this section we review of some of the detector's essential details.

The cognitive tutor gaming detector was designed using a psychometric modeling technique, Latent Response Models (Maris, 1995). This framework makes predictions at two levels: whether or not a specific action is gaming, and how often each individual student games. This multi-level modeling framework gives the model extra sensitivity in using all of the available data on the prevalence of gaming, across students.

The cognitive tutor gaming detector was trained on data from a combination of systematic classroom observations of whether a student was gaming (Baker, Corbett, Koedinger, & Wagner, 2004) and data about the student's pretest and posttest scores. The gaming detector is significantly better than chance at distinguishing students who game the system from nongaming students, and is also significantly better than chance at distinguishing students who game the system from students who display gaming-like behaviors as part of a broader pattern of focusing time and energy on the most challenging material (Baker, Corbett, & Koedinger, 2004; Baker, Corbett, Koedinger, & Roll, 2006). The cognitive tutor gaming detector searches for fast errors and help requests made on the same step across multiple problems, particularly when the student has never demonstrated proficiency on that step.

***Questionnaire.*** The questionnaire consisted of a set of self-report questions given along with the students’ unit pretest, to assess students’ motivations and beliefs. The questionnaire items were drawn from existing motivational inventories or from items used across many prior studies with this age group (as noted next, per question), and were adapted minimally (for instance, the words “the computer tutor” was regularly substituted for “in class,” and questions were changed from first-person to second-person for consistency). All items were pretested for comprehensibility with a student from the relevant age group before the study. Items were a combination of multiple choice and Likert-scale items, from 1 (Not at all) to 6 (Very much).

The questionnaire included items to assess:

- **Hypothesis H1: Whether the student was oriented towards performance or learning** (multiple choice; adapted from Mueller & Dweck, 1998)

“We are considering adding a new feature to the computer tutors, to give you more control over the problems the tutor gives you. If you had your choice, what kind of problems would you like best?

A) Problems that aren’t too hard, so I don’t get many wrong.
B) Problems that are pretty easy, so I’ll do well.
C) Problems that I’m pretty good at, so I can show that I’m smart
D) Problems that I’ll learn a lot from, even if I won’t look so smart.”

“Some classes that use computer tutors also have extra-credit projects. If you had your choice, what kinds of extra projects would you most like to do?

A) An extra-credit project that is easy, so I can get a better grade.
B) An extra-credit project where I could learn about things that interested me.
C) An extra-credit project in an area I’m pretty good at, so I can show my teacher what I know.
D) An extra-credit project that isn’t very difficult, so I don’t have to work too hard.

- **Hypothesis H13: The student’s level of anxiety about using the tutor** (Likert scale) (adapted from Harnisch, Hill, & Fyans, 1980)

“When you start a new problem in the tutor, do you feel afraid that you will do poorly?”

“When you are working problems in the tutor, do you feel that other students understand the tutor better than you?”

- **Hypothesis H5: How much the student liked using the tutor** (Likert scale) (adapted from Mueller & Dweck, 1998)

“How much fun were the math problems in the last computer tutor lesson you used?”

"How much do you like using the computer tutor to work through math problems?"

- **Hypothesis H4: The student's attitude towards computers** (Likert scale) (Frantom, Green, & Hoffman, 2002)

"How much do you like using computers, in general?"

- **Whether the student was lying or answering carelessly on the questionnaire** (2 choices) (Sarason, 1978)

"Is the following statement true about YOU? 'I never worry what other people think of me.' TRUE/FALSE"

Results from this study will be presented, along with the results of the other two studies, in section 5.

### Cognitive Tutor Study Two

***Study goals.*** The second study on the choice to game a Cognitive Tutor investigated several hypotheses including hypotheses H2 (desire for control), H3 (disliking mathematics), H8 (the belief that the tutor is not helpful for learning), H9 (the belief that computers/the tutor are uncaring), H10 (lack of educational self-drive), and H11 (passive-aggressiveness). This study was conducted in Spring 2005, after Cognitive Tutor Study One was analyzed, and was designed with the results of that study in mind (the results of both studies will be discussed in the next section).

***Participants.*** Cognitive Tutor Study Two was conducted in five classes at two schools in the Pittsburgh suburbs. All students were in the second semester of a year-long cognitive tutor course for middle school mathematics, and had used Cognitive Tutors multiple times a week for several months. Student ages ranged from approximately 12 to 14. One hundred eight (108) students completed all stages of the study; 13 other students were removed from analysis due to missing one or more parts of the study.

***Cognitive tutor curriculum.*** Cognitive Tutor Study Two involved two tutor lessons: the lesson on scatterplot generation and interpretation investigated in Cognitive Tutor Study One, and a lesson drawn from the same curriculum, on converting between percents and other mathematical representations (shown in Figure 3). Both lessons had been verified in earlier work to lead to significantly improved learning, on average. More detail on both lessons is given in Baker (2005). Forty-seven percent (47%) of the students used the scatterplot generation and interpretation lesson and the other 53% of the students used the lesson on converting between percents and other mathematical representations. Both lessons were used by students for 80 minutes.

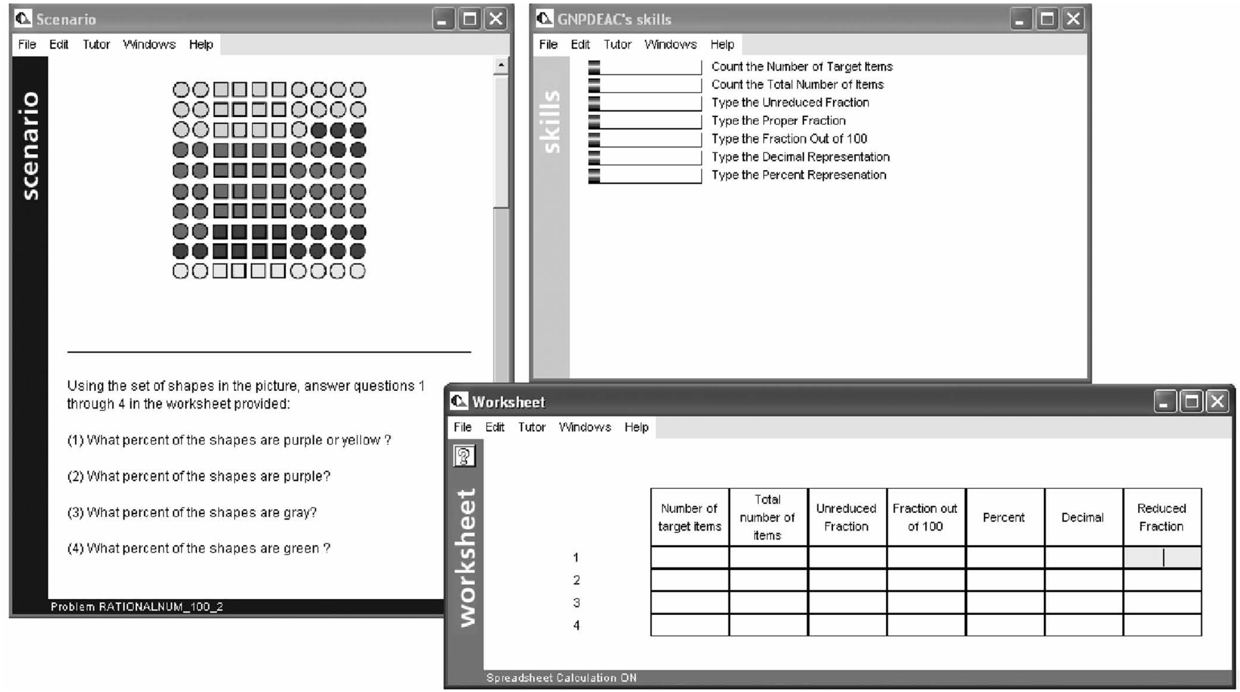


**Figure 3.** The Cognitive Tutor lesson on percents: The student answers questions about the diagram in the scenario (left) window, using a scaffold given within the worksheet (bottom-right) window. The tutor’s estimates of the student’s skills are shown in the skills window, at upper-right. Note that despite the two lessons being drawn from the same Cognitive Tutor curriculum, the student enters answers in a fairly different fashion, between lessons.

***Gaming behavior model.*** The same model of gaming behavior used in Cognitive Tutor Study One was used to assess each student's frequency of gaming behavior within Cognitive Tutor Study Two. The model has been shown to be effective in both lessons (Baker, Corbett, Koedinger, & Roll, 2006).

***Questionnaire.*** The questionnaire in Cognitive Tutor Study Two consisted of a set of self-report questions given along with the students' unit pretest, to assess students' motivations and beliefs. The questionnaire items were drawn from existing motivational inventories or from items used across many prior studies with this age group; some were adapted minimally, to shift their domain to the context of a tutoring system. All items were pretested for comprehensibility, but some students needed an explanation of the item "I feel that the tutor, in its own unique way, is genuinely concerned about my learning," during the actual study, because of difficulty interpreting the word "concerned" in this context. All questionnaire items in this study were given as Likert scales, from 1 (Strongly Disagree) to 6 (Strongly Agree).

The following items were used in the questionnaire.

- **Hypothesis H2 (desire for more control, expressed in reverse as the belief that computers/the tutor increase control)**

"Using the tutor gives me greater control over my work." (Dillon, Garner, Kuilboer, & Quinn, 1998)

"I am in complete control when I use a computer." (Selwyn, 1997)

- **Hypothesis H3 (disliking mathematics)**

"I enjoy working on a difficult math problem."

"Math is boring." (Knezek & Christensen, 1995)

- **Hypothesis H8 (believing the tutor is not useful)**

"The tutor's help system is effective in helping me complete problems." (Lewis, 1995)

- **Hypothesis H9 (believing computers/the tutor are uncaring)**

"I feel that the tutor, in its own unique way, is genuinely concerned about my learning." (Bickmore & Picard, 2004)

"The tutor treats people as individuals."

"The tutor ignores my feelings." (Cupach & Spitzberg, 1983)

- **Hypothesis H10 (lack of self-drive)**

"I study by myself without anyone forcing me to study."

"I try to finish whatever I begin" (Knezek & Christensen, 1995)

- **Hypothesis H11 (tendency towards passive-aggressiveness)**

  "At times I tend to work slowly or do a bad job on tasks I don't want to do."

  "I tend to try to get out of things by making up excuses."

  "I often forget things that I would prefer not to do." (Parker & Hadzi-Pavlovic, 2001)

- **Additional item (initially related to a broader version of Hypothesis H8)**

  "Most things that a computer can be used for, I can do just as well myself." (Selwyn, 1997)

Results from this study will be presented, along with the results of the other two studies, in the next section.

### ASSISTments Study

***Study goals.*** The third study on why students choose to game was also conducted in Spring 2005, at approximately the same time as Cognitive Tutor Study Two. The research in the third study was designed to address questions raised by Cognitive Tutor Study One, as well as address hypotheses not considered in that study. It was tailored to the ASSISTments System (Razzaq et al. 2007) and was designed to investigate several hypotheses, including H1 (Performance Goals), H3 (Disliking Mathematics), and H4 (Disliking Computers), H5 (Disliking the Learning Environment), H6 (Believing Mathematics is Not Important), H7 (Believing Mathematics Ability is Innate), H8 (Believing the Tutor is Not Helpful for Learning), H10 (Lack of Educational Self-Drive), H11 (Passive-Aggressiveness), and H12 (Frustration). The results of the study, along with the results of the two Cognitive Tutor studies, will be discussed in the Results section.

***Participants.*** Data for these hypotheses was collected by way of a survey administered to students who had been regularly using the ASSISTments system throughout the 2004-2005 academic year, on a biweekly basis. The students were from two urban schools and multiple classes (eight teachers) in Worcester, Massachusetts. About 600 students were using the system in 2004-2005. Only students who completed all stages of the study were included in the final dataset, which included data and responses for 323 students (Walonoski and Heffernan 2006a).

***ASSISTments curriculum.*** Unlike the studies conducted with the Cognitive Tutor curriculum, which were conducted using specific subsegments of the Cognitive Tutor curriculum, the studies conducted with the ASSISTments system involved problems drawn from the entire ASSISTments curriculum, involving data from an entire academic year drawn over many sets of problems grouped by mathematical topics.

***Gaming behavior model.*** In the ASSISTments study, each student's frequency of gaming behavior was calculated with a knowledge-engineered model of gaming behavior. The model calculated how frequently each student gamed based only on knowledge-engineered definitions of hint abuse and guessing-and-checking behavior (Walonoski & Heffernan, 2006b). The model only considered potential gaming behaviors that occur in clusters, based upon the finding from the Cognitive Tutor gaming model that gaming actions occur in clusters (Baker, Corbett, & Koedinger, 2004). Using the model, gaming rates were calculated for each student who completed an end-of-year survey.

We used this knowledge-engineered model to analyze our hypotheses within the ASSISTments study data, providing a potential contrast to the machine-learned model used to analyze the hypotheses in the Cognitive Tutor study data. It has been shown to be possible to develop a machine-learned model of gaming behavior within the ASSISTments data (Walonoski & Heffernan, 2006a). However, using a different detection approach with our ASSISTments study data considerably lowers the risk of bias in our analyses. The existing machine-learned model of gaming behavior in the ASSISTments system was developed using data features and a modeling framework heavily influenced by the earlier design of the Cognitive Tutor gaming detector. Hence any bias incorporated into the machine-learned model used to analyze the Cognitive Tutor data is likely to also be contained in a machine-learned model of gaming within the ASSISTments detector. In this way, if a consistent pattern of results is seen across the two systems, we will know that the pattern of results is inherent to gaming behavior rather than arising from biases in our detection method.

***Questionnaire.*** The ASSISTments survey consisted of 22 Likert-scale items, one Yes/No question, and two open response items. The Likert-scale items were on a 1-5 scale, with the options "Strongly Disagree," "Disagree," "Not Sure," "Agree," and "Strongly Agree." The survey questions were not developed to map in an exclusive one-to-one fashion to a list of hypotheses (unlike the Cognitive Tutor studies); hence, some of the items correspond to more than one hypothesis, and not all hypotheses are represented by an equal number of items. The mapping between hypotheses and items presented here was developed through concept mapping exercises and discussion between the authors.

The survey questions used in the ASSISTments study were as follows (Table 2).

Our statistical and quantitative analysis of this survey was restricted to the 22 Likert-scale questions and the single Yes/No question. The open-response questions were not classified or coded, since the analysis would necessarily be quite complex and time-consuming. However, rather than omit this data source entirely, we will discuss some of the open-responses in the next section, to illustrate the quantitative findings.

Results from the ASSISTments study will be presented, along with the results of the other two studies, in the Results section.

## RESULTS: EVIDENCE ON HYPOTHESES

In this section we will discuss the evidence in favor of and against each hypothesis. Evidence for and against each hypothesis is obtained by correlating the answers on the relevant questionnaire items to each student's frequency of gaming behavior, as detected by the models of gaming.

### Student Goals: H1 and H2

***H1: Performance goals.*** Both Cognitive Tutor Study One and the ASSISTments Study had items relating to the first hypothesis: students game the system because they have performance goals rather than learning goals. Cognitive Tutor Study One had two multiple-choice questions related to this hypothesis. Neither item showed a significant correlation between gaming and performance goals.

- "We are considering adding a new feature to the computer tutors, to give you more control over the problems the tutor gives you. If you had your choice, what kind of problems would you like best?"
  - o $r$= -0.03, $F(1,100)=0.09$, $p=0.76$
- "Some classes that use computer tutors also have extra-credit projects. If you had your choice, what kinds of extra projects would you most like to do?"
  - o $r$=-0.06, $F(1,100)=0.41$, $p=0.52$

The ASSISTments Study had five questions related to the performance goal hypothesis. Out of those five questions, four had no significant correlation. One question was marginally significantly, but weakly, correlated:

- "My goal when using the ASSISTment system was to get through as many items as possible."
  - o $r=0.10$, $F(1,323)=2.97$, $p=0.09$.

Overall, then, there is no strong evidence of a connection between performance goals and gaming, despite prior predictions that a connection would exist (Baker, Corbett, Koedinger, & Wagner, 2004; Martínez-Mirón et al., 2004). Neither item from Cognitive Tutor Study One was connected with gaming, and only one item out of five in the ASSISTments Study was even marginally significant, an overall pattern that would occur by chance a considerable percentage of the time. Thus, our data from across the two studies suggests that students do not game because of performance goals.

**Table 2**
Items Given in the ASSISTments Study. All Items Were Likert-Scale Unless Otherwise Noted.

| Question Text | Hypotheses |
|---|---|
| When a problem was too hard I would just try to get though a problem so that I could get into items that I could do. | H1 (Performance Goals)<br>H10 (Lack of Educational Self-Drive) |
| I tried to get through difficult problems as quickly as possible. | H1 (Performance Goals) |
| I think that being told the answer was more helpful than reading the hints. | H8 (Believing the Tutor is Not Helpful for Learning) |
| I took my work on the ASSISTment system very seriously and worked hard all the time. | H1 (Performance Goals)<br>H10 (Lack of Educational Self-Drive) |
| My goal when using the ASSISTment system was to get through as many items as possible. | H1 (Performance Goals) |
| My goal when using the ASSISTment system was to learn new things. | H1 (Performance Goals)<br>H10 (Lack of Educational Self-Drive) |
| I think that some people are just good at math. | H7 (Believing Mathematics Ability is Innate) |
| I like math class. | H3 (Disliking Mathematics) |
| I am good at math. | H3 (Disliking Mathematics) |
| I work hard at math. | H3 (Disliking Mathematics)<br>H6 (Believing Mathematics is Not Important)<br>H10 (Lack of Educational Self-Drive) |
| I do my homework in math class. | H6 (Believing Mathematics is Not Important)<br>H10 (Lack of Educational Self-Drive) |
| I believe that if I work hard at math I can do well. | H7 (Believing Mathematics Ability is Innate) |
| When I grow up I think I will use math in my job. | H6 (Believing Mathematics is Not Important) |

| Question Text | Hypotheses |
|---|---|
| Breaking a question down into smaller steps helped me understand how to solve similar problems. | H8 (Believing the Tutor is Not Helpful for Learning) |
| I think the hints helped me understand how to solve similar problems. | H8 (Believing the Tutor is Not Helpful for Learning) |
| I care a great deal about how well I do in math. | H6 (Believing Mathematics is Not Important)<br>H10 (Lack of Educational Self-Drive) |
| My parents think it's very important to do well in math. | H6 (Believing Mathematics is Not Important) |
| I found many of the items frustrating because they were too hard. | H12 (Frustration)<br>H8 (Believing the Tutor is Not Helpful for Learning) |
| I like learning from a computer. | H4 (Disliking Computers) |
| I think the ASSISTment system helped me prepare for the MCAS. | H8 (Believing the Tutor is Not Helpful for Learning) |
| I liked using the ASSISTment system better than doing my homework. | H5 (Disliking the Learning Environment) |
| I liked using the ASSISTment system better than doing a test. | H5 (Disliking the Learning Environment) |
| I liked using the ASSISTment system better than my normal classroom activity. | H5 (Disliking the Learning Environment) |
| Do you have a computer at home? (Yes/No item) | H4 (Disliking Computers) |
| Now assume you had internet access at home and that your teacher made it possible for you to do your homework either on paper or using the ASSISTment system. How much would you prefer to use the ASSISTment system? | H5 (Disliking the Learning Environment) |
| List three things you like most about the ASSISTments system. (open response item) | Potentially all hypotheses |
| List three things you dislike the most about the ASSISTment system. (open response item) | Potentially all hypotheses |

***H2: Desire for more control.*** Only Cognitive Tutor Study Two had elements relating to the second hypothesis: students game the system out of a desire for more control over their learning experience.

Cognitive Tutor Study Two had two Likert-scale questions relating to this hypothesis. Neither of them was significantly correlated with gaming the system.

- "Using the tutor gives me greater control over my work" (Dillon et al., 1998)
  - $r$= -0.10, $F(1,95)$=0.92, $p$=0.34.
- "I am in complete control when I use a computer" (Selwyn, 1997)
  - $r$=0.02, $F(1,95)$=0.04, $p$=0.85

### Student Attitudes: H3-H5

***H3: Disliking math.*** Cognitive Tutor Study Two and the ASSISTments Study featured elements relating to the third hypothesis: students game the system in an interactive learning environment because they dislike the subject matter taught in that learning environment.

In Cognitive Tutor Study Two, the evidence suggested a relationship between disliking mathematics and gaming, with both items relevant to that relationship pointing (relatively weakly) in that direction.

- "Math is boring" (Knezek & Christensen, 1995)
  - $r$=0.19, $F(1,95)$=3.47, $p$=0.07
- "I enjoy working on a difficult math problem" (Knezek and Christensen, 1995)
  - $r$= -0.15, $F(1,95)$=2.12, $p$=0.15

The ASSISTments Study found stronger evidence that disliking mathematics was significantly correlated with gaming. The correlations for the related questions are as follows:

- "I like math class."
  - $r$= -0.21, $F(1,323)$=14.89, $p$<0.001
- "I am good at math."
  - $r$= -0.26, $F(1,323)$=22.99, $p$<0.001
- "I work hard at math."
  - $r$= -0.13, $F(1,323)$=5.7, $p$=0.02

Hence, disliking the subject matter (mathematics, in these studies) appears to be associated with gaming the system in both learning environments.

Additional anecdotal support for this conclusion comes from the ASSISTments System open response items. About 8% of students who were in the top quartile of gamers listed "math" in their dislikes about the system.

Another 8% in that quartile said that they liked the system because they claimed it helped them learn math. No student whatsoever said they liked the system because of "math."

***H4: Disliking computers.*** Cognitive Tutor Study One and the ASSISTments Study both include questionnaire items that are related to the fourth hypothesis: students game the system because they dislike computers.

Cognitive Tutor Study One found that students who gamed the system (as assessed by the detector) liked computers significantly less than the other students.

- "How much do you like using computers, in general?"
  - o $r$= -0.20, $F(1,100)$= 4.37, $p$=0.04

The ASSISTments Study did not have any items directly addressing this hypothesis. One item involved how much students liked *learning* from a computer. This item was not significantly related to gaming.

- "I like learning from a computer."
  - o $r$= 0.05, $F(1,323)$=0.77, $p$=0.38

Hence, it appears that there is some evidence that disliking computers is associated with gaming, from Cognitive Tutor Study One, but there is no confirmation from the ASSISTments Study.

***H5: Disliking the learning environment.*** Both Cognitive Tutor Study One and the ASSISTments Study included items regarding the fifth hypothesis: that students game the system because they dislike the learning environment (but not necessarily computers in general).

Within Cognitive Tutor Study One, a student's attitude towards the tutor was significantly correlated to the choice to game the system (marginally in one case).

- "How much fun were the math problems in the last computer tutor lesson you used?"
  - o $r$= -0.19, $F(1,100)$=3.94, $p$=0.05
- "How much do you like using the computer tutor to work through math problems?"
  - o $r$= -0.16, $F(1,100)$=2.85, $p$=0.09

In relevant items in the ASSISTments Study, gamers were not found to be more likely to dislike the system.

- "I liked using the ASSISTment system better than doing my homework."
  - o $r$= -0.05, $F(1,323)$=0.79, $p$=0.37
- "I liked using the ASSISTment system better than doing a test."
  - o $r$= 0.02, $F(1,323)$=0.14, $p$=0.70

- "I liked using the ASSISTment system better than my normal classroom activity."
    - o $r$= 0.00, $F(1,323)=0.002$, $p=0.96$
- "Now assume you had internet access at home and that your teacher made it possible for you to do your homework either on paper or using the ASSISTment system. How much would you prefer to use the ASSISTment system?"
    - o $r$= -0.07, $F(1,323)=1.58$, $p=0.21$

Hence, although the Cognitive Tutor Study found significant correlation and support for this hypothesis, there was no such result in the ASSIStments Study. One possibility is that students dislike the two systems for different reasons, and thus the relationship between disliking the systems and gaming is different.

### Student Beliefs H6-H9

***H6: Math is not important.*** Only the ASSISTment Study had questions relating to the sixth hypothesis: that students game the system because they do not believe that the subject matter being taught is important (in this case, mathematics).

The ASSISTments Study had three questions relating (to at least some degree) to this hypothesis. None of these items were significantly correlated with gaming the system.

- "When I grow up I think I will use math in my job."
    - o $r$= -0.05, $F(1,323)=0.79$, $p=0.37$
- "I care a great deal about how well I do in math."
    - o $r$= -0.08, $F(1,323)=2.10$, $p=0.15$
- "My parents think it's very important to do well in math."
    - o $r$= 0.03, $F(1,323)=0.36$, $p=0.55$

***H7: Believing mathematics ability is innate.*** Only the ASSISTments Study had questions relating to the seventh hypothesis: that gaming the system stems from students' beliefs that mathematics ability is innate, and they will not be able to succeed whether they put in effort or not, presumably because they do not possess this innate ability.

- "I think that some people are just good at math."
    - o $r$= 0.06, $F(1,323)=1.31$, $p=0.25$
- "I believe that if I work hard at math I can do well."
    - o $r$= -0.12, $F(1,323)=4.49$, $p=0.04$

These results present mixed evidence on whether believing in mathematics as an innate ability is related to students gaming the system – it does appear that students who game the system do not believe that hard work will help them with mathematics, presenting evidence in favor of this hypothesis – however, the correlation is fairly modest, and not seen in the other item.

***H8: The tutor is not helpful for learning***. Both Cognitive Tutor Study Two and the ASSISTments Study featured questions relating to the eighth hypothesis: that students game the system because they believe that the tutor will not help them learn.

In Cognitive Tutor Study Two, the belief that the tutor's *help system* was not effective was marginally significantly correlated with gaming the system.

- "The tutor's help system is effective in helping me complete problems."
  - o $r$= -0.19, $F(1,95)$=3.29, $p$=0.07

The ASSISTments Study had four questions related to the eighth hypothesis, of which one was statistically significant. The significant item was related to the tutor's help system; however one nonsignificant item was also related to the tutor's help system.

- "I think that being told the answer was more helpful than reading the hints."
  - o $r$= 0.12, $F(1,323)$=4.61, $p$=0.03
- "Breaking a question down into smaller steps helped me understand how to solve similar problems."
  - o $r$= -0.04, $F(1,323)$=0.51, $p$=0.47
- "I think the hints helped me understand how to solve similar problems."
  - o $r$= 0.07, $F(1,323)$=1.37, $p$=0.24
- "I think the ASSISTment system helped me prepare for the MCAS."
  - o $r$= -0.04, $F(1,323)$=0.64, $p$=0.42

Hence, in both studies, there was some connection between not believing in the tutor's help systems and gaming the system – but it was only marginally significant in Cognitive Tutor Study Two, and inconsistent in the ASSISTments Study.

***H9: Computers/tutors are uncaring.*** Only Cognitive Tutor Study Two had questions related to the ninth hypothesis: students game the system because they believe that the tutor and/or computer does not (or cannot) care if they learn. The study had three questions related to this hypothesis:

- "I feel that the tutor, in its own unique way, is genuinely concerned about my learning."
  - o $r$= -0.05, $F(1,93)$=0.25, $p$=0.62
- "The tutor treats people as individuals"
  - o $r$= -0.13, $F(1,93)$=1.53, $p$=0.22
- "The tutor ignores my feelings"
  - o $r$= 0.09, $F(1,93)$=0.85, $p$=0.36

None of these questions had any significant correlation with gaming behavior. Hence, there does not appear to be any support for this hypothesis.

### Student Approaches: H10 and H11

***H10: Lack of education self-drive.*** Both Cognitive Tutor Study Two and the ASSISTments Study featured questions relating to the tenth hypothesis: students game the system because they lack self-drive, especially for completing tasks which do not personally motivate them.

Cognitive Tutor Study Two featured two items related to this hypothesis. One item had a significant correlation to gaming the system, and the other item had a marginally significant correlation.

- "I try to finish whatever I begin."
  - $r = -0.26$, $F(1,94)=6.25$, $p=0.01$
- "I study by myself without anyone forcing me to study."
  - $r = -0.18$, $F(1,94)=3.05$, $p=0.08$

The ASSISTments Study had eight questions related to this hypothesis, two of which were statistically significant or marginally statistically significant.

- "I work hard at math."
  - $r = 0.13$, $F(1,323)=5.7$, $p=0.02$
- "I do my homework in math class."
  - $r = -0.10$, $F(1,323)=3.39$, $p=0.07$
- "When a problem was too hard I would just try to get though a problem so that I could get into items that I could do."
  - $r = 0.02$, $F(1,323)=0.12$, $p=0.74$
- "I took my work on the ASSISTment system very seriously and worked hard all the time."
  - $r = -0.03$, $F(1,323)=0.35$, $p=0.55$
- "My goal when using the ASSISTment system was to learn new things."
  - $r=0.03$, $F(1,323)=0.24$, $p=0.62$
- "I care a great deal about how well I do in math."
  - $r = -0.08$, $F(1,323)=2.10$, $p=0.15$
- "I usually seek help when I don't understand something."
  - $r = -0.07$, $F(1,323)=1.56$, $p=0.21$

Since only two of the eight items relevant to this hypothesis in the ASSISTments Study favored this hypothesis, one significantly and the other marginally significantly, there is still a 24.5% chance this pattern of results within the ASSISTments Study was obtained by chance (computed using the properties of probability).

Hence, the evidence from Cognitive Tutor Study Two was unambiguously in favor of this hypothesis, but the ASSISTments Study's evidence was inconsistent and could be due to chance.

In the ASSISTment Study's open response section, many of the students in the top quartile of gaming behavior reported getting tired for various reasons, including too many problems, too many similar problems, too many words, and so forth. This reported tiredness might be related to the lack of self-drive.

***H11: Passive-aggressiveness.*** Only Cognitive Tutor Study Two had any questionnaire items relating to the eleventh hypothesis: that gaming the system is a type of passive-aggressive behavior.

- "At times I tend to work slowly or do a bad job on tasks I don't want to do."
  - o $r$=0.12, $F(1,94)$=1.25, $p$=0.27
- "I often forget things that I would prefer not to do." (Parker & Hadzi-Pavlovic, 2001)
  - o $r$=0.03, $F(1,94)$=0.14, $p$=0.71

Since neither of these items was significantly correlated with gaming the system, there is no evidence that passive-aggressiveness is associated with gaming the system.

## Student Emotions: H12 and H13

***H12: Frustration.*** Only the ASSISTments Study had any questions directly related to the twelfth hypothesis: frustration with the tutoring software causes the students to game the system.

- "I found many of the items frustrating because they were too hard."
  - o $r$=0.228, $F(1,322)$=17.06, $p$<0.001

Hence, frustration due to problem difficulty appears to be related to student choice to game the system.

Anecdotally, in the ASSISTment Study almost every single student in the top quartile of gaming expressed in the open response section one of their dislikes as being frustrated – more specifically, frustration due to problem difficulty, too many words to read, poor wording, and too many problems. Other students reported frustration much less often.

***H13: Anxiety.*** Only Cognitive Tutor Study One had any questions regarding the 13th hypothesis: students game the system because they feel anxious about using the tutoring software. The study had three questions addressing this area:

- "When you start a new problem in the tutor, do you feel afraid that you will do poorly?"
  - o $r$= -0.04, $F(1,100)$=0.13, $p$=0.71

- "When you are working problems in the tutor, do you feel that other students understand the tutor better than you?"
  - o $r$= -0.03, $F(1,100)$=0.13, $p$=0.72
- "When you use computers in general, do you feel afraid that you will do something wrong?"
  - o $r$= -0.02, $F(1,100)$=0.05, $p$=0.82

None of the responses to these questions were significantly correlated with gaming the system.

### Summary of Evidence

Overall, the results from these three studies appear to be consistent with the following hypotheses:

- H3: Dislike of the subject matter
- H10: Lack of educational self-drive
- H12: Frustration

In addition, the results from these studies appear to be consistent, at least partially, with the following hypotheses – although the results in these cases are not 100% certain.

- H4: Dislike of computers
- H5: Dislike of the learning environment
- H7: Belief that mathematics ability is innate
- H8: The tutor is not helpful for learning

Previous hypotheses, including performance orientation, anxiety, and perceiving mathematics to have low importance, do not appear to be associated with students' choices to game the system.

On a broad scale, it appears that gaming is associated with negative affective states. Students who game are likely to dislike the subject matter (H3), computers (H4), the learning environment (potentially) (H5), and to feel frustration (H12), and that the tutor is not helpful with learning (H8). There also appears to be some relationship between believing that effort is not helpful (H7) and is unenjoyable (H10).

The evidence from these three studies agrees with some of the predictions made by our teachers, but strongly disagrees with other predictions. The teachers thought that gaming was caused by frustration (H12) and lack of educational self-drive (H10); the results from the studies agree. However, a third category that teachers thought was related to student gaming was performance goals (H1), which the study results do not support. In addition, the teachers did not expect either disliking the subject matter (H3) or disliking computers (H4) to be related to gaming the system, though both were, and other hypotheses such as the belief of mathematics as an innate ability (H7), the idea of disliking the learning environment (H5) and the idea that the tutor is not helpful for learning (H8), were strongly predicted against by the teachers. Hence, the teachers appear to have gotten some key predictions correct, but in many other ways their intuitions were not accurate: it is worth noting, however, that on hypothesis H1, at least two research groups published the same (incorrect) prediction as the teachers.

Another interesting finding is that the characteristics associated with gaming are reasonably coherent between the Cognitive Tutors and ASSISTments. The two environments, while both based on cognitive models of student learning, have fairly different pedagogical characteristics and are used by different populations. In addition, the definitions of gaming behavior differed between the two environments and research groups. Despite these differences, there were strong commonalities between the patterns of student characteristics associated with gaming behavior in each environment. This suggests that the results obtained here are reasonably likely to be general across learning environments, rather than specific to a single learning environment. Since gaming has been observed in a wide variety of environments, it is possible that the results described here will also explain gaming behavior in learning environments beyond those described here.

In the following section, we discuss how it may be possible to design systems that respond not just to gaming when it occurs (Walonoski & Heffernan, 2006b; Baker, Corbett, Koedinger, Evenson, et al., 2006) but to the root causes that underlie students' decisions to game the system. Knowing that gaming the system is related to the presence of negative affective states opens the possibility that we can reduce gaming by improving students' affect.

## DESIGN IMPLICATIONS

Ultimately, the goal of the research discussed here is to inform the design of systems that will reduce or even eliminate student motivation to game the system, and, in turn, to improve students' learning. The results we obtain have many design implications for educational software, and we propose some new methods and discuss some existing methods to address the problems poised by our findings.

One possible solution is to pay more attention to problem difficulty. Giving items which are challenging but which students do not find too difficult is a delicate problem of balance (Vygotsky, 1978; Arroyo & Murray, 2002). But solving that problem offers the possibility of alleviating student frustration related to problem difficulty. This simple suggestion is consistent both with our findings in this article, and with evidence that harmful gamers game on the hardest steps (Baker, Corbett, & Koedinger, 2004). Making problems easier may have other motivational benefits as well. However, if implemented without care, it may reduce learning (Paas & Van Merrienboer, 1994). Alternatively, it may be possible to reduce frustration by offering more direct, concise, and unambiguous hints and feedback messages.

Providing shorter problems might also reduce frustration and dislike of the learning environment. Some problems within both systems are currently very long (six to nine steps with multi-level hints at each step, possibly with nested subproblems). If a problem is short, a student should be able to complete it in a few minutes. Completing many problems in a reasonably short time may increase students' feelings of accomplishment, and improve their self-drive within the tutor context. Similarly, shorter lessons or problem sets which are achievable in a single class period may increase students' feelings of accomplishment.

Another option is to allow students to skip problem steps or even entire problems, in another attempt to curb frustration related to problem difficulty and lack of control. The tutoring system could simply return to the skipped problem later to ensure that all the tutoring content is covered. The ability to skip problems could be tied to problem difficulty, student knowledge, and/or the student's rate of gaming.

A related way to address frustration with problem difficulty and lack of control associated with the learning environment would be to allow students to select the next problem or to take turns with the tutor in selecting the next problem (Mostow et al., 2002; Mitrovic & Martin, 2003). The selection process could possibly involve the display of problem previews or thumbnails, perhaps with associated difficulty information or subject identification. Simply by providing an element of choice, even among limited and similar options, may give students just enough control over the environment that they're looking for.

While there are many potential techniques for addressing frustration with the learning environment, some factors associated with gaming, such as disliking computers or mathematics, seem on first glance to be beyond the scope of what can be easily addressed within interactive learning environment. It is hard to know how we can change those perceptions directly. However, by addressing the other problems, and having minimally-frustrating tutoring systems with learning environments that students think are fun, perhaps it will become possible to develop environments that succeed even for students who dislike both computers and the subject matter.

## CONCLUSION

In this article, we have presented four studies about what motivations, attitudes, and affective states are associated with the choice to game. Two studies investigated these issues within the context of Cognitive Tutors, correlating students' self-reports with their gaming behavior as assessed by a machine-learned detector. Two other studies investigated these issues within the ASSISTments system. One ASSISTments study correlated students' self-reports with their gaming behavior as assessed by a rationally developed detector. The other ASSISTments study investigated teachers' beliefs of why students game the system.

Interestingly, despite the fairly different methods used in these studies, a reasonably consistent overall profile of gaming students can be seen across the studies. Across studies with two different systems, we found that disliking the software's subject matter (H3) and lack of self-drive (H10) are associated with a student's choice to game. Other constructs such as frustration (H12), disliking computers (H4) and the learning environment (H5), believing that mathematics ability is innate (H7), and believing that the tutor is not helpful for learning (H8), were associated with the choice to game in at least one of the three studies on student behavior and motivation. These constructs may be worth investigating in future studies.

Perhaps the biggest surprise from our studies regards the relationship between performance goals and gaming (H1). Performance goals were hypothesized both in prior research on gaming (Baker, Corbett, Koedinger, & Wagner, et al., 2004; Martinez-Miron et al., 2004) and by teachers experienced with using the ASSISTments system in class, to be a major driving factor for why students game, but none of the three studies on student behavior and motivation found any evidence for a relationship between performance goals and gaming behavior.

Overall, the teachers' hypotheses about gaming were only partially correct. The teachers correctly predicted that lack of self-drive (H10) and frustration (H12) would be associated with gaming, but did not predict the strong relationship between gaming and disliking the subject matter (H3). The teachers, like the researchers, predicted a relationship between gaming and performance goals that was not found (H1). Given the incomplete match between the teachers' predictions and our results, the results of the three studies on student motivation presented here may be of use to teachers who use interactive learning environments in their classes, enabling them to respond to gaming more effectively.

Understanding why students choose to game is useful in multiple ways. As discussed in the introduction, gaming the system occurs in many types of educational software, and is associated with significantly worse learning across several prior studies. Understanding why students choose to game systems is a key step towards developing systems that students do not choose to game, and training teachers who use interactive learning environments in their classrooms, to improve learning outcomes for all students. In addition, these modified systems may be more appropriate and more effective for students who experience the same affective states as students who game, but who do not choose to game themselves. In addition, understanding why students game educational systems may give insight on other problems within human-computer interaction. Abuse and misuse of interactive technology has become recognized as an increasing problem within human-computer interaction as a field (De Angeli, Brahnam, Wallis, & Dix, 2006). It is possible that our findings about this type of software misuse may shed light on why other users choose to misuse other types of interactive technology.

## References

Aist, G., Kort, B., Reilly, R., Mostow, J., Picard, R. (1996, June). Experimentally augmenting an intelligent tutoring system with human-supplied capabilities: Adding human-provided emotional scaffolding to an automated reading tutor that listens. *Proceedings of the 2nd International Conference on Intelligent Tutoring Systems*, (pp. 992-1005), Montreal, Canada.

Aleven, V. (2001, October). *Helping students to become better help seekers: Towards supporting metacognition in a cognitive tutor.* Paper presented at the German-USA Early Career Research Exchange Program: Research on Learning Technologies and Technology-Supported Education, Tubingen, Germany.

Aleven, V., McLaren, B.M., Roll, I., & Koedinger, K.R. (2004, August) Toward tutoring help seeking: Applying cognitive modeling to meta-cognitive skills. *Proceedings of the 7th International Conference on Intelligent Tutoring Systems* (*ITS2004*, pp. 227-239), Maceió, Brazil.

Aleven, V., McLaren, B.M., Roll, I., & Koedinger, K.R. (2006). Toward meta-cognitive tutoring: A model of help seeking with a cognitive tutor. *International Journal of Artificial Intelligence in Education, 16*, 101-130.

American Psychiatric Association (1994). *Diagnostic and statistical manual of mental disorders: DSM-IV*. Washington, DC: American Psychiatric Publishing.

Anderson, J.R., Corbett, A.T., Koedinger, K.R., & Pelletier, R. (1995). Cognitive tutors: Lessons learned. *Journal of the Learning Sciences, 4(*2), 167-207.

Arbreton, A. (1998). Student goal orientation and help-seeking strategy use. In S.A. Karabenick (Ed.), *Strategic help seeking: Implications for learning and teaching* (pp. 95-116). Mahwah, NJ: Lawrence Erlbaum.

Arroyo, I., & Murray, T. (2002, June). Towards measuring and maintaining the zone of proximal development within the AnimalWatch intelligent tutoring system. *Proceedings of the 6th International Conference on Intelligent Tutoring Systems (ITS 2002)* Biarritz, France.

Arroyo, I., & Woolf, B. (2005, July). Inferring learning and attitudes from a Bayesian network of log file data. *Proceedings of the 12th International Conference on Artificial Intelligence in Education*, (pp. 33-40), Amsterdam, The Netherlands.

Baker, R.S. (2005). *Designing intelligent tutors that adapt to when students game the system.* Doctoral dissertation, Carnegie Mellon University, Pittsburgh, PA. Published as CMU Technical Report CMU-HCII-05-104.

Baker, R.S., Corbett, A.T., & Koedinger, K.R. (2004, August). Detecting student misuse of intelligent tutoring systems. *Proceedings of the 7th International Conference on Intelligent Tutoring Systems*, (pp. 531-540), Maceió, Brazil.

Baker, R.S.J.d., Corbett, A.T., Koedinger, K.R., Evenson, E., Roll, I., Wagner, A.Z., et al. (2006, June). Adapting to when students game an intelligent tutoring system. *Proceedings of the 8th International Conference on Intelligent Tutoring Systems*, (pp. 392-401), Jhongli, Taiwan.

Baker, R.S.J.d., Corbett, A.T., Koedinger, K.R., & Roll, I. (2006, June). Generalizing detection of gaming the system across a tutoring curriculum. *Proceedings of the 8th International Conference on Intelligent Tutoring Systems*, (pp. 402-411), Jhongli, Taiwan.

Baker, R.S., Corbett, A.T., Koedinger, K.R., & Wagner, A.Z. (2004, April). Off-task behavior in the cognitive tutor classroom: When students "game the system." *Proceedings of ACM CHI 2004: Computer-Human Interaction*, (pp. 383-390), Vienna, Austria.

Beal, C.R., Qu, L., & Lee, H. (2006, July). *Classifying learner engagement through integration of multiple data sources*. Paper presented at the 21st National Conference on Artificial Intelligence (AAAI-2006), Boston, MA.

Baker, R.S., Roll, I., Corbett, A.T., & Koedinger, K.R. (2005, August). Do performance goals lead students to game the system? *Proceedings of the International Conference on Artificial Intelligence and Education* (*AIED2005*; pp.57-64), Amsterdam, The Netherlands.

Beck, J. (2005, June). Engagement tracing: Using response times to model student disengagement. *Proceedings of the 12th International Conference on Artificial Intelligence in Education* (*AIED 2005*, pp. 88-95) Amsterdam, The Netherlands.

Bickmore, T.W., & Picard, R.W. (2004). Towards caring machines. *CHI Extended Abstracts*, (pp. 1489-1492).

Carnegie Learning (2002). *Cognitive tutor: Summary of results report*. Retrieved February 26, 2008, from http://www.carnegielearning.com/web_docs/summary_of_results.pdf

Cheng, R., & Vassileva, J. (2005, June). Adaptive reward mechanism for sustainable online learning community. *Proceedings of the 12th International Conference on Artificial Intelligence in Education*, (pp. 152-159), Amsterdam, The Netherlands.

Cordova, D. I., & Lepper, M. R. (1996). Intrinsic motivation and the process of learning: Beneficial effects of contextualization, personalization, and choice. *Journal of Educational Psychology, 88*(4), 715–730.

Corbett, A.T., & Anderson, J.R. (1995). Knowledge tracing: Modeling the acquisition of procedural knowledge. *User Modeling and User-Adapted Interaction, 4*, 253-278.

Cupach, W.R., & Spitzberg, B.H. (1983). Trait versus state: A comparison of dispositional and situational measures of interpersonal communication competence. *The Western Journal of Speech Communication, 47*, 364-379.

De Angeli, A., Brahnam, S., Wallis, P., & Dix, A. (2006, April). *Proceedings of the CHI2006 workshop on Misuse and Abuse of Interactive Technologies* (pp. 1647-1650), Montreal, Canada.

Dillon, T.W., Garner, M., Kuilboer, J., & Quinn, J.D. (1998). Accounting student acceptance of tax preparation software. *Journal of Accounting and Computers, 13*, 17-29.

Dweck, C.S. (2000). *Self-theories: Their role in motivation, personality, and development.* Philadelphia, PA: Psychology Press.

Frantom, C.G., Green, K.E., & Hoffman, E.R. (2002). Measure development: The children's attitudes toward technology scale (CATS). *Journal of Educational Computing Research, 26*(3), 249-263.

Harnisch, D.L., Hill, K.T., & Fyans, L.J. (1980, April). *Development of a shorter, more reliable, and more valid measure of test motivation*. Paper presented at the 1980 Annual Meeting of the National Council on Measurement in Education, Boston, MA. (ERIC Document Reproduction Service No. ED193273)

Johns, J., & Woolf, B. (2006, July). *A dynamic mixture model to detect student motivation and proficiency*. Paper presented at the 21st National Conference on Artificial Intelligence (AAAI-2006), Boston, MA.

Kelley, T., & Littman, J. (2001). *The art of innovation: Lessons in creativity from IDEO, America's leading design firm*. New York: Doubleday.

Klawe, M.M. (1998, November). Designing game-based interactive multimedia mathematics learning activities. *Proceedings of UCSMP International Conference on Mathematics Education*, Chicago,IL.

Knezek, G., & Christensen, R. (1995). *Computer attitudes questionnaire.* Denton, TX: Texas Center for Educational Technology.

Koedinger, K.R., Anderson, J.R., Hadley, W.H., & Mark, M. (1997). Intelligent tutoring goes to school in the big city. *International Journal of Artificial Intelligence in Education, 8*, 30-43.

Lewis, J.R. (1995). IBM computer usability satisfaction questionnaires: Psychometric evaluation and instructions for use. *International Journal of Human-Computer Interaction, 7*(1), 57-78.

Magnussen, R., & Misfeldt, M. (2004, December). Player transformation of educational multiplayer games. *Proceedings of Other Players*, Copenhagen, Denmark. Retrieved February 26, 2008, from http://www.itu.dk/op/proceedings.htm

Maris, E. (1995). Psychometric latent response models. *Psychometrika, 60*(4), 523-547.

Martínez-Mirón, E.A., du Boulay, B., & Luckin, R. (2004, August). Goal achievement orientation in the design of an ILE. *Proceedings of the ITS2004 Workshop on Social and Emotional Intelligence in Learning Environments*, (pp. 72-78), Maceió, Brazil.

McCrae, R.R., & Costa, P.T. (1990). *Personality in adulthood*. New York: Guilford University Press.

Mitrovic, A., & Martin, B. (2003, July). Scaffolding and fading problem selection in SQL-tutor. *Proceedings of the 11th International Conference on Artificial Intelligence in Education*, (pp. 479-481), Sydney, Australia.

Mostow, J., Aist, G., Beck, J., Chalasani, R., Cuneo, A., Jia, P., et al. (2002, June). A la recherche du temps perdu, or As time goes by: Where does the time go in a reading tutor that listens? *Proceedings of the 6th International Conference on Intelligent Tutoring Systems*, Biarritz, France.

Mueller, C.M., & Dweck, C.S. (1998). Praise for intelligence can undermine children's motivation and performance. *Journal of Personality and Social Psychology, 75*(1), 33-52.

Murray, R.C., & vanLehn, K. (2005, June). Effects of dissuading unnecessary help requests while providing proactive help. *Proceedings of the 12th International Conference on Artificial Intelligence in Education*, (pp. 887-889), Amsterdam, The Netherlands.

Paas, F., & Van Merrienboer, J. (1994). Variability of worked examples and transfer of geometry problem-solving skills: A cognitive-load approach. *Journal of Educational Psychology, 86*, 122-133.

Parker, G., & Hadzi-Pavlovic, D. (2001). A question of style: Refining the dimensions of personality disorder style. *Journal of Personality Disorders, 15*(4), 300-318.

Pettitt, L. (1995, April). *Middle school students' perception of math and science abilities and related careers*. Paper presented at the 61st Biennial Meeting of the Society for Research in Child Development, Indianapolis, IN.

Razzaq, L., Heffernan, N.T., Koedinger, K., Feng, M., Nuzzo-Jones, G., Junker, B., et al. (2007). A web-based authoring tool for intelligent tutors: Assessment and instructional assistance. In N. Nedjah, (Eds.), *Intelligent educational machines*. Berlin: Springer-Verlag.

Rhodewalt, F. (1994). Conceptions of ability, achievement goals, and individual differences in self-handicapping behavior: On the application of implicit theories. *Journal of Personality, 62*, 67-85.

Sansone, C., Wiebe, D.J., & Morgan, C. (1999). Self-regulating interest: The moderating role of hardiness and conscientiousness. *Journal of Personality, 67*(4), 701- 733.

Sarason, S.B. (1978). *Anxiety in elementary school children: A report of research*. Westport, CT: Greenwood Press.

Schiefele, U. (1991). Interest, learning, and motivation. *Educational Psychologist, 26*(3&4), 299-323.

Schofield, J.W. (1995). *Computers and classroom culture*. Cambridge, UK: Cambridge University Press.

Selwyn, N. (1997). Students’ attitudes towards computers: Validation of a computer attitude scale for 16-19 education. *Computers & Education, 28*, 35-41.

Stevens, R., & Soller, A. (2005). Machine learning models of problem space navigation: The influence of gender. *Journal of Computer Science and Information Systems, 2*(2), 83-98.

Stipek, D., & Gralinski, J.H. (1996). Children’s beliefs about intelligence and school performance. *Journal of Educational Psychology, 88*(3), 397-407.

Stone, M.H. (1993). *Abnormalities of personality: Within and beyond the realm of treatment*. New York: W.W. Norton.

Venkatesh, V., & Davis, F.D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science, 46*(2), 186-204.

Vygotsky, L. (1978). *Mind and society: The development of higher mental processes*. Cambridge, MA: Harvard University Press.

Walonoski, J.A., & Heffernan, N.T. (2006a,June). Detection and analysis of off-task gaming behavior in intelligent tutoring systems. In Ikeda, Ashley & Chan (Eds.), *Proceedings of the 8th International Conference on Intelligent Tutoring Systems*, (pp. 382-391), Jhongli, Taiwan. Berlin: Springer-Verlag.

Walonoski, J.A., & Heffernan, N.T. (2006b, June). Prevention of off-task gaming behavior in intelligent tutoring systems. In Ikeda, Ashley & Chan (Eds.), *Proceedings of the 8th International Conference on Intelligent Tutoring Systems*, (pp. 722-724), Jhongli, Taiwan. Berlin: Springer-Verlag.

Wood, H., & Wood, D. (1999). Help seeking, learning, and contingent tutoring. *Computers and Education, 33*, 153-169.

# Appendix

## One Version of the Teacher Survey

Dear Teacher. We are investigating why some student's might engage in "Gaming" behavior with the ASSISTment system. By gaming we mean subverting the software to complete problems without having to learn: for example, abusing the hints by clicking through the hints to get the answer, or systematic guessing (trying every answer in multiple choice questions, or answering 1,2,3,4,5,6…). We want your opinion on why students might game.

This is a list of possible reasons: Please mark your top three guesses below on why students game with a 1, 2, or 3. Also, mark any reasons that you think are clearly **not** related to student gaming with an X.

### Student Goals

______ Having performance goals instead of learning goals: Student think their goal should be to get through as many items as possible as opposed to learning to answer the questions that they don't know how to do.

______ Desire For More Control: ASSISTments do not provide the student with enough control over their learning, so they game to reassert more control.

### Student Attitudes

______ Disliking Mathematics: Student game because they do not like mathematics

______ Disliking Computers in general: Student game because they do not like working with computers.

______ Disliking the ASSISTment system in specific.

### Student Beliefs

______ Believing mathematics is not important

______ Believing that students do well or poorly at math because of their innate mathematical ability, instead of their effort

______ Believing the ASSISTment system is Not Helpful For Learning

______ Believing the ASSISTment system is Uncaring

### Student General Approaches

______ Students game the system because **they lack self-drive**, especially for completing tasks which do not personally motivate them.

______ Students who are generally passive-aggressive game the system in order to resist a task they don't like without appearing to be doing so

### Student Emotions

______ Frustration: Student game because they are frustrated.

______ Students game because they feel Anxiety

Remember to mark any reasons that you think are clearly **not** the cause of student gaming with an X.

Do you have any comments, or guesses or hypotheses that we missed?