Understanding Wheel Spinning in the Context of Affective Factors

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Abstract. The notion of wheel spinning, students getting stuck in the mastery learning cycle of an ITS without mastering the skill, is an emerging issue. Although wheel spinning has been analyzed, there has been little work in understanding what factors underlie it, and whether it occurs in cultural contexts outside that of the United States. This work analyzes data from 116 students in an urban setting in the Philippines. We found that Filipino students using the Scatterplot Tutor exhibited wheel spinning behaviors. We explore the impact of an intervention, Scooter the Tutor, on wheel spinning behavior and did not find that it had any effect. We also analyzed data from quantitative field observations, and found that wheel spinning is negatively correlated with flow, positively correlated with confusion, but not correlated with boredom. This result suggests that the problem of wheel spinning is primarily cognitive in nature, .and not related to student motivation. However, wheel spinning is positively correlated with gaming the system, so those constructs seem to be related.

Keywords: wheel spinning, affect, quantitative field observations, gaming the system.

There has been a long history of work in on mastery learning with computer-based education [1, 2], and this model makes intuitive sense and certainly realizes the maxim of "practice makes perfect," particularly as most tutors provide assistance to the student in the form of hints or breaking the problem into steps. However, a bit of thought reveals some hidden weaknesses in the model. If a student requires assistance to solve the first two problems, presenting a third with the hope the student will learn the skill could very well be a sensible strategy. If the student has been unable to solve twenty practice opportunities, and required considerable help on all of them, it is probably rather optimistic to believe that the twenty-first opportunity will enable the student to suddenly acquire the skill. Using data from 116 students in an urban setting in the Philippines [9], this paper explores wheel spinning--the phenomenon of students being stuck on a particular skill--investigates what other constructs relate to it, and discusses possible approaches for remediation.

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1 Investigating Student Mastery in the Scatterplot Tutor

The testbed for this study was the Cognitive Tutor unit on scatterplot generation and interpretation [3]. Sixty-four of the participants (experimental) were randomly assigned to use a version of the tutor with an embodied conversational agent, "Scooter the Tutor". Scooter was designed to both reduce gaming the system and to help students learn the material that they were avoiding by gaming while affecting non-gaming students as minimally as possible [4]. In order to investigate how students mastered content in the Scatterplot Tutor, we made use of the log files recorded during the study to analyze student performance.

How did students spend their time in the Scatterplot Tutor? We separate students into three categories of learners on any given problem. The first type is those still working towards mastery. The second type is those who have just mastered the skill on that problem. The third type is those learners who have mastered the skill on a previous problem. For purposes of this paper, we use a definition of mastery to be defined as three correct responses in a row. Figure 1 shows how many students were engaged in each of these three activities for the first 20 practice opportunities of each skill. The graph goes up to 2610, since there are 24 skills in the Scatterplot Tutor, and 116 students (some students did not attempt all of the skills). Therefore, on the first practice opportunity, all students are working towards mastering the skill, as none could have mastered it yet (since the definition is three correct responses in a row). On the third practice opportunity, a fair proportion of the students master the skill. By the seventh practice opportunity, relatively few students are still working towards mastery, and those students are unlikely to master the skill. The majority of students are working on additional practice of the skills, and possibly overpractice [6]. Whether all of this overpractice is wasted or even preventable [7] is debatable; however we were surprised at the low number of students, both in absolute terms and as a relative proportion, still working towards mastering the skill by the 9th practice opportunity.

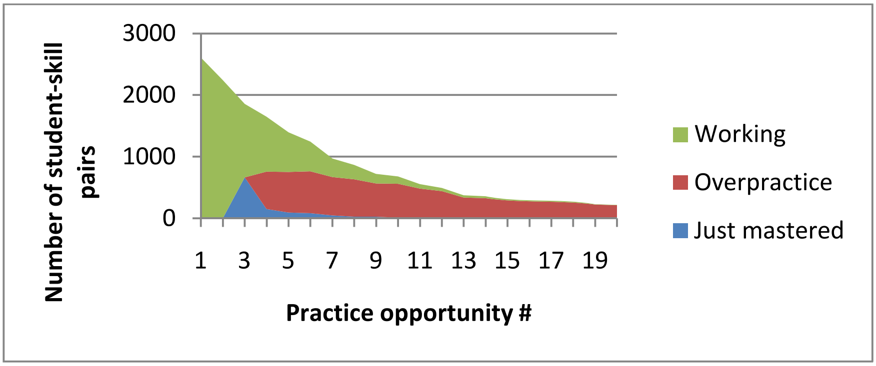

Fig. 1. Number of students engaged in each type of activity as a function of practice opportunity

Do students wheelspin within the scatterplot tutor? The phenomenon of wheel spinning [8] refers to students who fail to master a skill in a computer tutor in a timely manner. If we only consider students who attempt 3 or more problems, and wait until the 15^{th} practice opportunity, only 63.2% of students will have mastered the skill. Waiting until 20 practice opportunities results in very few additional students mastering the skill (63.4%), as relatively few students will attempt to solve that many problems. In short, students who master the material in the Scatterplot Tutor tend to do so quickly; after 7 practice opportunities 90% of the students who will eventually master the skill have already done so.

These results, combined with Figure 1, which demonstrates that relatively few students succeed in mastering a skill relative to the number working on it, suggest that Filipino students working in the Scatterplot Tutor are capable of exhibiting wheel spinning behavior. After a student has attempted 10 problems on a skill, if he has not yet mastered it, then he has little hope of doing so through additional interaction with the ITS. For consistency with prior research, we also adopt a threshold of 10 problems for our cutpoint for wheel spinning. That is, if a student reaches 10 problem attempts on a skill without mastery, we define him as exhibiting wheel spinning behavior on that skill.

2 Understanding the Interplay of Scooter the Tutor, Affect, and Wheel Spinning

For interpreting the affect data, in order to obtain scientifically meaningful results, we restricted the data in two ways. First, as mentioned previously, we excluded students who solved a small number of problems (<60). Second, we found that certain affective states were rarely observed by our coders.

Given the lack of statistical power, and extreme non-normality of the data, we did not examine the affect states of Frustration or Surprise. That left us with Confusion, Flow, Boredom, Neutral, and Delight, as well as our measure of percent time gaming the system and percent of skills on which the student wheel spun.

Both the control and experimental groups worked with the Scatterplot Tutor. In addition, the experimental group received feedback and assistance from Scooter the Tutor. One question is whether Scooter had an impact on the affective states or on the amount of wheel spinning. The impact of Scooter on affective states has been previously studied [9], and this work replicates the finding of no statistically reliable differences as a result of Scooter. We also measured Scooter's impact on wheel spinning, and found that in both conditions the mean was 0.37; so there appears to be no impact from Scooter. Given that Scooter also included instruction, it is somewhat surprising that the rate of wheel spinning was not affected.

What is the interrelationship between affect and wheel spinning? To further explore wheel spinning, we examined how the other constructs we measured correlated with it. As we expected student incoming knowledge to directly affect both wheel spinning and affective measures such as confusion and flow, we computed partial correlations, partialing out the student's pretest score. Table 1 provides the results of the partial correlations. Wheel spinning is moderately related to flow and confusion, both in the expected direction with flow meaning a student is less likely to wheel spin and confusion making a student more likely to wheel spin. There is also a moderately strong relationship with gaming the system. Perhaps most interestingly, boredom was not strongly related to wheel spinning, with a partial correlation of 0.145.

Table 1. Partial correlations vs. wheel spinning

Construct	Partial correlation	p-value
Flow	-0.523	1.03×10^{-8}
Confusion	0.476	2.91×10^{-7}
Gaming the system	0.437	3.24×10^{-6}
Boredom	0.145	0.14
Delight	0.053	0.59

Combined, these results suggest that students are wheel spinning not because of affective factors where they are not motivated to do the work, but rather, students are genuinely stuck on the material and need additional instructional support. To test this intuition formally, we modeled the problem in Tetrad, a freely available tool for causal discovery in datasets[1]. We restricted our analysis to only consider confusion, boredom, and flow, as these variables were the most related to wheel spinning, and they were also the states that had the most observations by the human coders. In addition, we included domain pretest score, wheel spinning, and gaming the system in the model. Figure 2 provides the result of our analysis within Tetrad. We used the Tetrad's PC search algorithm to discover the structure, and its estimator functionality to estimate the model coefficients. We first normalized the data to make the coefficient magnitudes comparable. In addition, we set as background knowledge that the pretest score was causally upstream from all of the other variables.

The interpretation of Figure 2 is that an arrow from one node to another means there is a *direct* relation between the two. There are several interesting implications from Figure 2. First, Tetrad's search agrees that wheel spinning is related to cognitive factors such as confusion, but not to boredom. Second, the search suggests that gaming is causally downstream of wheel spinning, and is a function of both affective (boredom) and cognitive (confusion) factors. This analysis of course is limited by the statistical power of the dataset, and by the variables entered into the analysis.

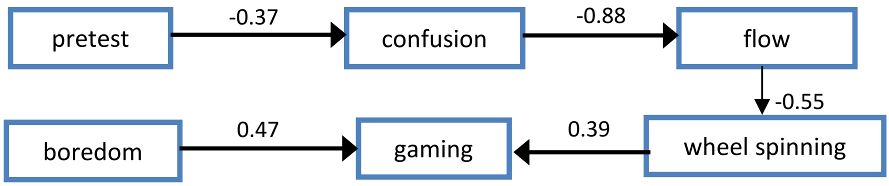

Fig. 2. Path model of wheel spinning, gaming, and affective states

[1] http://www.phil.cmu.edu/projects/tetrad/

3 Contributions, Future Work, and Conclusions

This work advances the state of knowledge for the field in several ways. First, it places the phenomenon of wheel spinning in a broader research context. Prior work was restricted to exploring students in the United States [8], while this work establishes that it occurs in at least one non-Western population. Futhermore, this work examines overpractice and wheel spinning, and finds that there are many more students engaged in overpractice than are making progress towards mastery.

This work also examined factors that could influence the rate of wheel spinning. This work replicates and extends prior research linking gaming and wheel spinning [8]. The prior research used a custom-built gaming detector that had not been well validated [10]. This work uses a well-validated detector of gaming [5] with broadly similar results in that wheel spinning and gaming appear to be linked. In addition, the direction of causality between gaming the system and wheel spinning was unclear. This work presents evidence that wheel spinning is caused by a deficit in student knowledge, which in turn causes gaming the system. In addition to cognitive factors, gaming the system also appears to be caused by affective factors, such as student boredom. These findings are consistent with prior work that found that boredom was more likely than chance to lead to gaming the system [11].

Third, this work investigated whether a tutorial intervention, Scooter the Tutor, could influence the amount of wheel spinning. Scooter addresses both behavioral issues as he is triggered by gaming behavior, as well as cognitive deficits through his instructional lessons. Although wheel spinning is related to cognitive deficits, Scooter was not found to be an effective intervention in this study.

There are several interesting next steps to take from this work. One avenue is to find an intervention that is capable of affecting the rate of wheel spinning. It would also be interesting to perform a fuller analysis of how wheel spinning relates to affective states. For this study, we were limited by the low rates of frustration and surprise in the set of analyses we were able to conduct. In particular, we suspect frustration and wheel spinning are related.

In summary, this paper investigates wheel spinning. We have found that wheel spinning exists in non-Western populations, and is related to knowledge deficits rather than student boredom. As a consequence, wheel spinning is best addressed via cognitive, rather than affective, interventions.

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