Impact of Student Achievement Goals on CS1 Outcomes

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ABSTRACT
Achievement goals are cognitively-represented end states that individuals strive to reach in competence situations. Well-studied by educational psychologists, achievement goals are robust predictors of grades, interest, and motivation of students. In this paper, we apply achievement goal theory to measure CS1 students’ achievement goals and consequent interest in CS and final exam grade. We find that students aiming for topic mastery become interested in CS and, contrary to theoretical expectations, perform well on the exam. A more complex pattern of results surrounds students who orient toward competence demonstration or normative comparison, and the link between such performance goals and outcomes is less clear. We argue for the continued appropriation of educational theory to inform our studies of CS success.

1. INTRODUCTION
Why are some students successful in CS1 and others are not? The answers that we uncover depend on at least three choices: the predictors that we measure, the outcome measures that we collect, and the particulars of the learning process and how the course is taught. Many researchers have investigated this question, but often make these choices in similar ways. Studies often investigate predictors that are thought to be unique to the CS context, collect exam grade or final course grade as the outcome measure of success, and do so in a lecture-based CS1. Authors have since argued that all three decisions should be problematized in the CS research literature: we should consider theory-based predictors from other subject domains, measure outcomes such as interest and self-efficacy in addition to course grades, and do so in courses where new pedagogical tools are in use [21].

Researchers have recently used achievement goal theory to investigate links between students’ achievement goals and interest, enjoyment, and grades in CS1 [22]. They found that achievement goals relate to these CS1 outcomes, but in ways discordant with the educational psychology literature in which the framework was developed. In the present paper, we replicate and extend the main findings of that work using a different student pool and different measures of achievement goals that disaggregate larger performance goal constructs. We find that students oriented toward subject mastery become interested in CS and perform well on the CS1 final exam. On the other hand, aiming to outperform peers or publicly demonstrate competence can in some cases be positively related to exam grade, but the link is comparatively less clear.

2. LITERATURE REVIEW

2.1 Predicting CS1 Performance
As carefully outlined by Robins [17], the CS education community has been long intrigued by the possibility of finding factors that separate programmers from non-programmers. Researchers have considered cognitive capacity, learning style, personality, developmental, and other factors that might explain why some students readily succeed at programming compared to others. Research, however, remains inconclusive and contradictory on most if not all of these factors [2]. Mathematical ability is a robust and powerful predictor of programming ability, but it is unclear whether this link measures anything beyond the obvious link between intelligence and programming aptitude [17]. In addition to persevering in the search for discipline-specific predictors, we might make additional progress using predictors known to be important in other domains. While such predictors are unlikely to explain the alleged bimodal distribution in CS1 [17], for two reasons we believe this line of inquiry remains worthwhile. First, there is recent debate around the bimodality of such grades, and we might search for discipline-specific predictors, we might make additional progress using predictors known to be important in other domains. While such predictors are unlikely to explain the alleged bimodal distribution in CS1 [17], for two reasons we believe this line of inquiry remains worthwhile. First, there is recent debate around the bimodality of such grades, and whether there really are two separate student populations [13]. Second, it may be that grades are indeed bimodal, but other valued outcomes are not.

2.2 Interest as Valued Outcome
The grade earned by students on exams or in the course itself is one important measure of what has been learned. Indeed, many studies take grades as the sole measure of CS1 success [3, 20].

As noted by educational psychology researchers [10], however, interest in a foundational course can be more important than grades for determining whether students continue to enroll in further courses in that discipline. Early work in CS education suggested that students take CS courses for many reasons, including enjoyment working with computers, desire for a high-paying job, challenging material, and
Table 1: Summary of Achievement Goals.

<table>
<thead>
<tr>
<th>Goal</th>
<th>Brief Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mastery</td>
<td>Learn and master the course material</td>
</tr>
<tr>
<td>Performance-</td>
<td>Show others that one is smart and/or good at class-work</td>
</tr>
<tr>
<td>Appearance</td>
<td></td>
</tr>
<tr>
<td>Performance-</td>
<td>Perform better than other students</td>
</tr>
<tr>
<td>Normative</td>
<td></td>
</tr>
</tbody>
</table>

2.3 Achievement Goals

The goals adopted by students can have dramatic effects on course performance and intrinsic interest [9]. Achievement goal theory examines those achievement-related goals that reflect the desire to develop, attain, or demonstrate competence [9]. Research suggests two particularly important types of achievement goals: mastery goals and performance goals. A summary of these achievement goals appears in Table 1.

Mastery Goals: Mastery goals are self-referential, focusing on task-based standards or, more commonly, personal improvement. Students with such goals try to learn as much as possible and are thought to seek challenge and persist through difficulty. There is much to suggest the adaptive nature of mastery goals. For example, students that adopt mastery goals are thought to involve themselves deeply in learning processes, use elaborative study strategies, and become interested in academic domains [19]. Indeed, much early literature espoused a mastery goal perspective, arguing that mastery goals should be the sole type of goal adopted by students, and that any positive effects associated with adopting performance goals would be outweighed by their drawbacks [11].

Performance Goals: The effects of performance goals have been much contested, in no small part due to the performance goal label subsuming at least two separable goal types [11]. One type of performance goal is related to appearance: demonstrating competence to peers or teachers, possibly also with an evaluative component based on outperforming others. The other type of performance goal is purely normative: trying to competitively outperform others with regard to objective standards. This distinction is important, because appearance goals are typically negatively related to course performance, whereas normative goals tend to be positively related to course performance [11].

Multiple Goals: A multiple goals perspective acknowledges the possibility that mastery and performance goals can each contribute to desirable interest and performance outcomes. One statistical pattern supporting this perspective occurs when performance goals predict one valued outcome and mastery goals predict another [19]. For example, one study [10] used a longitudinal design in order to investigate the relationship between achievement goals and interest and performance outcomes. The authors found that students who adopted mastery goals became more interested in psychology and enjoyed lectures more than students who did not adopt mastery goals. On the other hand, students who adopted performance goals earned higher grades in the course and higher semester GPA than did students lacking performance goals. Each type of goal was therefore indicative of a desirable outcome. Outperforming others is not inconsistent with attaining task mastery, and this is borne out by data showing that students can simultaneously adopt both goal strivings [9].

Goals in CS: In a previous study of achievement goals in CS1, the author found support for the mastery goal perspective [22]. Mastery goals were positively related to exam grade, enjoyment of CS1, and interest in CS. Performance goals, on the other hand, were negatively related to exam grade and, in one section of the course but not the other, were related to lower interest and enjoyment in CS. This is at odds with the findings in educational psychology research [19], suggesting that optimal goal strivings in CS may be different than those in other academic areas. However, in that CS1 study, the two facets of performance goals described earlier — appearance and normative — were aggregated into a single performance goal measure. Indeed, not until recently has the importance of separating these strivings been acknowledged [11]. To that end, the goal of the present study is to examine relationships between achievement goals (mastery, appearance, and normative) with valued outcomes (grades and interest in CS).

3. METHOD

3.1 Study Context

We report on a CS1 course taught in Fall 2014 at an undergraduate campus of a large research-intensive university. The course was taught using the Peer Instruction (PI) pedagogy. Briefly, this involves a shift away from lecture and toward classes driven by conceptual questions. Students use clickers to respond to these questions and engage their peers in deliberations over the correct answer. For recent reviews of PI in CS, and expected benefits in terms of learning and instruction, see [16, 23, 24].

The instructor began the course by introducing the rationale for using PI, covering some of the research findings and goals for the peer discussions. Prior to each lecture, students completed a reading quiz; the instructor read the responses to help shape the following lecture. The reading quizzes were graded based on completion (not correctness) and were worth 4% of students’ final grade; in-class clicker participation accounted for a further 5% of students’ grade. Each lecture was focused on three to four PI questions, with mini-lectures interspersed when planned by the instructor or when performance was poor. The course instructor was a lecturer with significant PI and CS teaching experience, and had taught CS1 using PI several times.

The course took place over 12 weeks, with three 50-minute lectures and one lab session per week. Students were enrolled in one of two sections, both lockstepped in delivery (including the same assignments and exams) and taught by the same instructor. Python was used as the programming language through which traditional imperative CS1 topics were taught. In the final three weeks of class, some CS2 topics were briefly introduced: sorting, complexity, and object-oriented programming.
3.2 Questionnaire Administration

At the start of the semester, students were invited to participate in the research study. Students were introduced to the field of Computer Science Education, and were told that the purpose of the study was to understand whether and why particular types of students succeed in CS courses. This information, along with a link to the first questionnaire, was included in the introductory course slides and sent by email to all students. A small course credit was given to students who completed both waves of the study; students received this credit whether or not they opted to allow us to use their responses in data analysis.

Goals Wave: The first questionnaire was made available for two weeks beginning at the start of the semester. The items (all seven-point, from “not at all” to “very”) were intended to measure students’ adoption of mastery, appearance, and normative goals. The mastery and normative items were obtained from the Achievement Goal Questionnaire - Revised [6], and the appearance goal items were taken from the Patterns of Adaptive Learning Scales (PALS) instrument [14]. (Some of the PALS items were slightly modified to remove references to importance in favour of explicit goal strivings.) The reliability of each scale was adequate, with Chronbach’s alphas of 0.77 (mastery), 0.93 (appearance), and 0.82 (normative). These questionnaire items appear in the appendix.

Interest Wave: In week 10, students were reminded in class that the study contained two questionnaires and that the second questionnaire would now be made available. Again, students were emailed a link to the questionnaire. This questionnaire contained 7-point items assessing students’ interest in CS and enjoyment of the specific course and are based on items used by Harackiewicz et al. [10]. Those authors distinguish interest from enjoyment by conceptualizing interest as a substantive interest (“hold” interest) and enjoyment as an affinity for specific course features (“catch” interest). The questionnaire was accessible after students had received most of their graded term work but before the study break leading to the final exams. The interest scale (see appendix) proved highly reliable ($\alpha = 0.91$), but the reliability of the enjoyment scale was low ($\alpha = 0.51$). We therefore do not report further on the enjoyment scale.

Grades: As a measure of course performance, we use students’ final exam grade. This is preferred to course grade as a whole because students worked with partners on labs and assignments, and those measures necessarily confound ability with the ability of their partner and effort in general. Final exams are far from perfect measures of ability [15, 19], but do match the usage in the vast majority of those CS1 studies concerned with student performance.

3.3 Data Analysis

Table 2 details the distributions of the continuous variables; together, the range and standard deviation (SD) suggest considerable spread in response choices. Table 3 contains the zero-order correlations below the diagonal and associated p-values above the diagonal. Across both sections, 298 students wrote the final exam, and 135 (45%) provided all of the required data for the study. The final dataset for this study contained 125 students: 7 students were removed because they spent less than 30 seconds on one or both questionnaires, and a further 3 were removed because their influence statistics were large. (Re-running the models with these students included does not change the overall results.) There was no statistically significant difference between course sections in initial goals, interest in CS, or exam grade, so data were collapsed across sections for analysis. In addition, gender was not a significant predictor in any model (on its own or interacting with other predictors), and so gender was similarly excluded.

Multiple linear regression was used to test the effects of goals on final exam grade and interest in CS. Initial models were constructed to include mastery goals, appearance goals, normative goals, and all two-and three-way interactions. Continuous variables were centred but not standardized. Higher-order interactions were removed from models when nonsignificant. None of the models violated assumptions of constant variance or autocorrelation [8]. The residuals of the interest model were non-normal according to a Shapiro-Wilk normality test. While the non-normality was correctable using a power transformation and did slightly improve the model fit, it did not affect the significance of coefficients. Therefore, to facilitate comparisons with the grade model, we report on the untransformed interest scores and resultant model.

4. RESULTS

Table 4 contains the coefficients, standard errors, and significance symbols for each of the two regression models. As an example of interpreting this table, consider the Mastery row. It shows that a one-point increase in mastery goals is associated both with a 0.40 increase in interest and a 4.75% increase in exam grade. The stars affixed to each number show that these relationships are both statistically significant. The Intercept row gives the mean interest score and exam grade for students at the midpoint of each of the goal predictors.

4.1 Interest

The overall interest model was found to be significant ($f(3, 121) = 7.75, p = 0$). Mastery goals were positively and significantly related to interest in CS ($t = 3.80, p = .0002$), and appearance performance goals were negatively related to interest in CS ($t = -2.03, p = .04$).
Table 4: Multiple regressions for interest in CS and exam grade. $a:b$ is used to denote the interaction between $a$ and $b$.

<table>
<thead>
<tr>
<th>Interest</th>
<th>Exam Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>5.67***</td>
</tr>
<tr>
<td>Mastery</td>
<td>0.40***</td>
</tr>
<tr>
<td>Normative</td>
<td>0.06</td>
</tr>
<tr>
<td>Appearance</td>
<td>-0.13</td>
</tr>
<tr>
<td>Normative:Appearance</td>
<td>-3.13***</td>
</tr>
</tbody>
</table>

$R^2$ = 0.16, Adj. $R^2$ = 0.14

Table 5: Interaction of appearance and normative performance goals on final exam grade (%).

<table>
<thead>
<tr>
<th>Appearance</th>
<th>low</th>
<th>medium</th>
<th>high</th>
</tr>
</thead>
<tbody>
<tr>
<td>low</td>
<td>59</td>
<td>62</td>
<td>65</td>
</tr>
<tr>
<td>medium</td>
<td>67</td>
<td>63</td>
<td>59</td>
</tr>
<tr>
<td>high</td>
<td>75</td>
<td>65</td>
<td>54</td>
</tr>
</tbody>
</table>

5. DISCUSSION

5.1 Who Becomes Interested in CS?

We find that mastery goals are positively correlated with interest, normative goals are not significantly correlated with interest, and appearance goals are negatively correlated with interest. The mastery link with interest is well-documented in other fields [10]; perhaps more surprising is the negative link between appearance goals and interest. Why might this be so in CS, particularly a PI-based CS? Indeed, the finding appears counterintuitive. Consider one of the appearance statements: “One of my goals is to show others that I’m good at my class work”. PI, with its focus on group discussion and argumentation, gives students many opportunities to show their peers that they are “good” at their class work. One might therefore expect students who score highly on such appearance items to enjoy PI and thereby become interested in CS. However, the opposite was found. This may be a case where student interviews could yield fruitful results.

In the meantime, we offer one hypothesis: perhaps it is difficult in PI discussions for students to prove that they are good at their class work! We strive for one- to two-thirds of students to answer each PI question incorrectly. In such circumstances, it is unlikely that students can answer many questions correctly on their own. This motivates the group discussions as students work collaboratively and pool their knowledge resources to arrive at a correct answer. Appearance-goal students may want to demonstrate their knowledge, but are unable to do so without the group discussion and argumentation. That is, these students might prefer to be able to tell their groupmates the correct answer to each question rather than negotiate the correct answer. There is evidence that performance-oriented students do exhibit unique behaviour patterns in group settings; for example, they are intolerant to ideas that are obviously wrong and dismiss inaccurate information [19]. It is worth pursuing this understanding further, particularly the possible effects of appearance-oriented students on others in their group.

5.2 Who Does Well in CS?

Replicating previous findings [22], we find a positive correlation between mastery goals and exam grade. This result is unexpected if one holds to a multiple goals perspective. In considerable educational psychology research, mastery goals are unrelated to grades [10, 18]. Furthermore, the multiple goals perspective contends that performance goals do positively correlate with grades, but we do not find clean evidence of that here. Appearance goals can positively correlate with exam grade, but only when normative goals are low. Similarly, normative goals can positively correlate with exam grade, but only when appearance goals are low. Striving for both types of performance goals simultaneously is maladaptive. As mastery goals do not interact with these performance goals and are independently and positively predictive of exam grade, our evidence presented here supports a
mastery goal perspective. We hypothesize that our results in CS differ from findings in other fields due to different styles of exams and effective means for studying for those exams.

5.2.1 Differing Examination Practices

If we compare our CS exams to typical introductory psychology exams, differences are immediately apparent: psychology exams are often normatively-graded multiple-choice exams, whereas CS1 exams tend toward comprehensive code-writing [10, 15]. The exam for the present course consisted of large code-writing questions, multiple-choice questions, and code-explaining and tracing questions, in approximate thirds. Some contend that performance-goal students, with their superficial study strategies, can perform well on multiple-choice tests but not tests requiring synthesis and integration [18]. Yet, recent research suggests that performance goals are in fact more adaptive than mastery goals on difficult tasks compared to easy tasks [18]. Understanding why and how performance goals operate in the face of difficult material may help us remedy the unclear link between performance goals and CS1 exam grades.

As ancillary analyses, we separately investigated both the multiple-choice and code-writing portions of the exam. The pattern of findings remained intact; in particular, mastery goals positively predicted these subsets of exam grades. Therefore, on both small conceptual questions and integrative questions, it appears that mastery goals are advantageous. Methodical research on this point is warranted.

5.2.2 Differing Student Studying Strategies

We know from the achievement goal literature that mastery and performance goals are each associated with a somewhat distinct set of study practices [5, 19]. The core distinction in study practices is between surface strategies (e.g. memorizing, re-reading) and deep strategies (e.g. elaborating). Though both mastery and performance goals have been associated with both types of studying, mastery goals are more often linked to deep strategies and performance goals are more often linked to surface strategies [5]. One reason that mastery-focused students may perform well on exams is that their mastery goals can lead to deep study strategies which in turn can lead to increased exam grades. We wonder to what extent this may be uniquely true in CS. Others have noted the tightly-interconnected nature of CS concepts [17], so that if a student fails to learn one topic then they are increasingly likely to fail to learn future topics. Given such coupling, it seems plausible that deep study strategies, where students make connections between topics and seek synthesis of ideas, would prove advantageous on exams. This suggests that educators should explicitly model and encourage connection-building between concepts, both to highlight the ways that concepts tend to relate and interact in CS, and to encourage this integrative approach to studying and learning.

6. CONCLUSION

The CS education research community has gamely proposed and studied numerous predictors of CS success, with mixed results. Under-studied, however, is the appropriation of theoretical frameworks from other disciplines that might prove to be useful in CS as well. To this end, we have continued the nascent investigation of achievement goal theory as the guiding framework. We find that goals do predict performance and interest in CS1. Mastery goals positively predict interest and exam grades, whereas some performance goals are negatively related to interest and interact to positively or negatively predict exam grades. It seems worthwhile to continue this investigation: if we can clearly link goal strivings and success, then we might be able to influence students’ achievement-related behaviour and thereby their interest and grades in CS1. We encourage the community to take up these concerns as we further discover what achievement goal theory can teach us about student success.

7. REFERENCES

APPENDIX

A. MASTERY AND PERFORMANCE

These questions make up the mastery- and performance-goal scales, as asked of students on the start-of-course questionnaire. Mastery and performance labels were not included. Indicate the extent to which each statement is true of you from 1 (not at all) to 7 (very):

Mastery [6]:
- My aim is to completely master the material presented in this class.
- I am striving to understand the content of this course as thoroughly as possible.
- My goal is to learn as much as possible.

Performance, appearance [14]:
- One of my goals is to have other students in my class think I am good at my class work.
- One of my goals is to show others that I'm good at my class work.
- One of my goals is to show others that class work is easy for me.
- One of my goals is to look smart in comparison to other students in my class.
- I aim to look smart compared to others in my class.

Performance, normative [6]:
- My aim is to perform well relative to other students.
- I am striving to do well compared to other students.
- My goal is to perform better than the other students.

B. INTEREST

These questions make up the interest scale, as asked of students on the end-of-course questionnaire. Indicate the extent to which each statement is true of you from 1 (not at all) to 7 (very) [10]:

- I think what we are learning in this class is interesting.
- I think I will be able to use what I learn in this course in other courses.
- I would recommend this class to others.
- I am enjoying this computer science class very much.
- I think the field of computer science is very interesting.
- This class has been a waste of my time.
- I'm glad I took this class.
- I think the course material in this class is useful for me to learn.
- I would like to take more computer science classes after this one.
- I am more likely to register for another computer science class because of my experience in this course.