The Role of Achievement Goal Orientation on Metacognitive Process Use in Game-Based Learning

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Abstract. To examine relations between achievement goal orientation—a construct of motivation, metacognition and learning, multiple data channels were collected from 58 students while problem solving in a game-based learning environment. Results suggest students with different goal orientations use metacognitive processes differently but found no differences in learning. Findings have implications for measuring motivation using multiple data channels to design adaptive game-based learning environments.

Keywords: Motivation · Metacognition · Game-based learning environments

1 Introduction

Students engage in self-regulation by monitoring and adjusting cognition, affect, metacognition, and motivation to attain learning goals [1]. Game-based learning environments (GBLEs) are effective tools for addressing the educational challenges of the 21st century and preparing the future workforce of the United States [2–4]. Research on GBLEs reveals students are more likely to achieve learning objectives and demonstrate more engagement while problem solving compared to classrooms [5, 6]. Research suggests students with different motivational states use SRL processes differently, revealing differences in learning outcomes [7, 8]. This study examined relationships between AGO and metacognitive process use by analyzing multiple data channels in conjunction with self-report and performance data before, during, and after problem solving with Crystal Island (CI).

2 Methods

2.1 Participants, Materials, and Experimental Procedure

58 undergraduates from a North American university participated in the study (M_{age} = 20.12, SD = 1.57), and students were compensated $10/hr. Upon consent, students were

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randomly assigned to one of three conditions, but the control condition was only analyzed. Self-report measures, demographics, and a 21-item, multiple-choice pretest and posttest (M_{pre} = .58, *SD* = .13; M_{post} = .68, *SD* = .14) were administered before and after problem solving with CI [5]. The Achievement Goal Questionnaire-Revised (AGQ-R) [9] was the only self-report data included in analyses (αs > .84). CI is a narrative-based GBLE where students play the role of a scientist to identify a pathogen source by interacting with non-player characters, reading books and articles, and scanning food items. Students were given tools to foster SRL processes: (1) concept matrix and (2) diagnosis worksheet. Students had to submit a correct diagnosis worksheet to complete the game. Students sat in front of a computer where they completed pretest materials and problem solved with CI (*M* = 81 min, *SD* = 23) and then completed a posttest.

2.2 Coding and Scoring

A proportional learning gain formula that considers prior knowledge while calculating differences between pre and posttest scores was used (*M* = .22, *SD* = .33) [10]. Total metacognitive processes were extracted from log files of all student actions for analyses. AGQ-R scores were summed and separated into four scores: mastery, performance, approach and avoidance. Two grouping variables with three levels each: (1) mastery, performance, and combined mastery and performance and (2) approach, avoidance, and combined approach and avoidance were created, and students were assigned based on how high they scored compared to other levels, where if students scored less than a 2-pt difference, they were assigned to the combination group.

3 Results

3.1 RQ1: Are There Differences Between AGO Groups on Proportional Learning Gain (PLG) After Problem Solving with CI?

A one-way ANOVA was conducted to assess if there were significant differences in PLG between AGO groups after problem solving with Crystal Island. Our results found no significant differences in PLG between AGO groups ($p > .05$).

3.2 RQ2: Are There Differences Between AGO Groups on the Frequency of Metacognitive Process Use While Problem Solving with CI?

A nonparametric Friedman test was conducted to examine differences between AGO groups on frequency of using metacognitive processes with Crystal Island. Our analysis revealed significant differences between AGO groups in frequency of metacognitive process use, $\chi^2(5) = 207.52$, $p = .000$. These findings support our hypothesis where we expected to see differences in frequency of metacognitive processes between AGO groups. See Table 1 for mean ranks between groups. Follow up related-samples Wilcoxon signed rank tests revealed differences between AGO groups on the frequency of reading complex text (i.e., research articles and books combined), between mastery, performance, and combined mastery and performance orientations ($z = 6.627$, $p = .000$, $r = .87$) and approach, avoidance, and combined approach and avoidance orientations ($z = 6.627$, $p = .000$, $r = .87$). There were also differences in frequency of using the concept matrix between mastery, performance, and combined mastery and performance orientations ($z = 6.627$, $p = .000$, $r = .87$) as well as approach, avoidance, and combined approach and avoidance orientations ($z = 6.627$, $p = .000$, $r = .87$). Analyses revealed differences in the frequency of scanning food items between mastery, performance, and combined mastery and performance orientations ($z = 6.625$, $p = .000$, $r = .87$) and approach, avoidance, and combined approach and avoidance orientations ($z = 6.624$, $p = .000$, $r = .87$). Additional analyses found differences in frequency of submitting diagnosis worksheets between mastery, performance, and combined mastery and performance orientations ($z = 6.569$, $p = .000$, $r = .86$) and approach, avoidance, and combined approach and avoidance orientations ($z = 6.568$, $p = .000$, $r = .86$).

Table 1. Mean ranks of metacognitive process use between AGO groups.

Groups	Metacognitive process use			
	Complex text	Concept matrix	Diagnosis worksheet	Food item scans
Mastery	18.21	18.21	3.36	15.93
Performance	13.71	13.71	2.79	16.00
Mastery/Performance combination	13.64	13.64	5.29	16.86
Approach	16.64	16.64	3.07	20.14
Avoidance	12.43	12.43	3.57	16.07
Approach/Avoidance combination	15.71	15.71	4.50	11.71

3.3 RQ3: Are There Differences Between AGO Groups on the Proportion of Time Engaging in Metacognitive Processes While Problem Solving with CI?

A nonparametric Friedman test was calculated to examine differences between AGO groups on the proportion of time engaging in metacognitive processes while problem solving with Crystal Island. Analysis revealed differences between AGO groups on proportion of time engaging in metacognitive processes, $\chi^2(5) = 274.08$, $p = .000$. See Table 2 for mean ranks between groups. Follow up related-samples Wilcoxon signed rank tests revealed differences in proportion of time in reading (e.g., research articles and books) between mastery, performance, and combined mastery and performance groups ($z = -6.624$, $p = .000$, $r = -.87$) and approach, avoidance, and combined approach and avoidance groups ($z = -6.624$, $p = .000$, $r = -.87$). There were differences in proportion of time using the concept matrix between mastery, performance and combined mastery and performance orientations ($z = -6.624$, $p = .000$, $r = -.87$) and approach, avoidance and combined approach and avoidance groups ($z = -6.624$,

$p = .000$, $r = -.87$). Analyses also found differences in proportion of time using the diagnosis worksheet between mastery, performance, and combined mastery and performance groups ($z = -6.624$, $p = .000$, $r = -.87$) and approach, avoidance, and combined approach and avoidance groups ($z = -6.624$, $p = .000$, $r = -.87$). There were also differences between mastery, performance and combined mastery and performance groups in proportion of time scanning food items ($z = -6.624$, $p = .000$, $r = -.87$) and approach, avoidance, and combined approach and avoidance groups ($z = -6.624$, $p = .000$, $r = -.87$).

Table 2. Mean ranks for proportional duration of metacognitive use between AGO groups.

Groups	Metacognitive process use			
	Complex text	Concept matrix	Diagnosis worksheet	Food item scans
Mastery	21.43	2.57	15.86	6.29
Performance	22.00	5.57	13.86	9.43
Mastery/Performance combination	20.79	7.64	16.36	7.50
Approach	21.21	4.36	15.50	8.21
Avoidance	22.07	7.07	15.64	8.79
Approach/Avoidance combination	21.36	5.64	14.64	6.21

3.4 RQ4: Do AGO Scores Predict Frequency and Proportion of Time Engaging in Metacognitive Processes While Problem Solving with CI?

Analyses revealed a significant linear regression where AGQ-R scores predicted proportion of time engaging in metacognitive processes, $F(4, 54) = 7.202$, $p = .000$ with an R^2 of .286. Specifically, the higher mastery-oriented students were, less time was used on the concept matrix ($\beta = -.827$, $p = .000$), while the higher avoidance-oriented students were, more time was used on the concept matrix ($\beta = .544$, $p = .005$).

4 Discussion

Examining how achievement goal orientation affects metacognition and learning is the first step to understanding how motivation affects SRL processes while problem solving with GBLEs. Understanding what personally motivates students to learn and factors which influence motivation could propel the development of adaptive GBLEs that consider the students' motivational needs to maximize metacognitive process use and learning. Future research should use multiple data channels instead of relying on self-report and performance data collected *before* and *after* problem solving as it does not capture changes in motivation. If GBLEs could detect motivation by analyzing eye-gaze behaviors, concurrent verbalizations, and facial expressions, the system could detect motivational changes based on how students interact with features of the system and adapt features to meet motivational needs. However, the first step is operationalizing motivation as dynamic and complex states that are likely to change across tasks.

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