THE INTEGRATION OF A PROBLEM-SOLVING BASED MEASURE OF TRANSFER IN A DIGITAL GAME-BASED LEARNING ENVIRONMENT

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Abstract

Determining the extent to which digital game-based learning environments (GBLEs) facilitate the transfer of learning is a critical challenge for the field. This study focused on the development, integration, and testing of a transfer activity completed after game play in the GBLE *Missions with Monty*. *Missions with Monty* is focused on improving science literacy, while specifically targeting metacomprehension skills for informational text. In this study fifth-grade students (*n* = 104) played a module called *Missing Monty* over the course of 5 weeks and completed a dilemma-based transfer task external to the game environment. Research questions sought to determine the impact of both playing the GBLE and also motivation on transfer performance. Regression analyses revealed that both science prior knowledge and knowledge gains after playing *Missing Monty* were significant predictors of transfer, importantly indicating the impact of learning in the GBLE on transfer performance. Interestingly, none of the measured motivational variables including self-efficacy, goal orientation, or interest were significant predictors.

Keywords: Transfer, science literacy, game-based learning, motivation.

1 INTRODUCTION

Recent meta-analyses have reported positive findings across the GBLE landscape with regard to learning outcomes [1][2]. However, there is much less clarity on the impact of GBLEs on the transfer of learning outside the game environment, mostly because of the scant literature on the topic. Transfer of learning involves the ability to apply learning from one context to problems in a new context [3]. Recent findings appear mixed. An examination of one of the most prevalently studied literacy GBLEs, *GraphoLearn*, showed numerous learning outcomes for elementary school students compared to a control group but no transfer effects for reading fluency, reading comprehension, or spelling [4]. Alternatively, others have shown successful transfer of learning with executive function skills for undergraduate students [5] and for middle-school students related to microbiology curriculum [6].

This lack of clarity on transfer effects extends to the relationship between motivation and transfer both in traditional environments and in GBLEs. One recent study reported positive effects of a growth mindset inducement for transfer effects with secondary students on science topics [7], The authors attributed this impact of mastery goals on cognitive load perceptions. Another study found that mastery-approach goal orientations for undergraduate students predicted knowledge transfer in a problem-solving exercise, except for students in conditions where the instructions emphasized performance outcomes [8]. However, in one of the few studies that examined the relationship between motivation and transfer within a GBLE, no positive relationships were found between self-efficacy or goal-orientations and transfer performance for 5th grade students learning landforms, map navigation, and map models curriculum [9].

Missions With Monty is a GBLE focused on improving 5th graders' science literacy. More specifically the program targets metacomprehension skills for informational texts aligned with classroom science

curriculum. The program promotes self-regulated learning (SRL) and focuses on ecosystems curriculum. In the current study, students engaged with the *Missing Monty* module. The scenario involves the player filling the role of a promising young science professor traveling to work with Monty, a monitor lizard and world-renowned scientist known for his ability to solve real-life problems. Monty has created Wildlife University (WU) in a remote rainforest. The students and professors at WU are animals of many different types focused on becoming more scientifically literate in order to save their natural habitats. Unfortunately, upon arrival at WU the player is presented with two major problems to solve: 1) Monty has gone missing and 2) WU has been recently closed due to animals getting sick. Students then proceed to take on the role of a researcher seeking to solve these two overarching problems by collecting key information from various animal researcher sites. They begin by participating in a Strategy Training Camp led by animal characters and then visit animal researchers in their home environments to read their research and undergo metacomprehension gamified challenges presented by each character. Eventually, students narrow their information on a detective board and present their final hypothesis for the sickness. In sum, students are provided with numerous distributed practice cycles under the guidance of the game characters that function as pedagogical agents.

The primary purpose of the current study was to determine the extent to which GBLEs, in this case *Missing Monty*, facilitate knowledge transfer. Secondarily, we tested the extent to which motivational variables such as self-efficacy, goal-orientation, and interest contribute significant unique variance in predicting transfer over and above the impact of prior knowledge and knowledge gained within the GBLE.

2 METHODOLOGY

Fifth-grade students (n = 105) with a mean age of 10.72 years (45.2 % girls; 51.0% boys; 2.9% preferred not to identify) from public schools in North Carolina, USA participated as part of regular classroom instruction. Demographics included students from the following backgrounds: 62% White, 13% Hispanic or Latin American, 10% Black or African American, 4% two or more races, 3% other, 1% Asian, 1% Native American/Pacific Islander/Alaska Native.

All students completed a *pre and posttest of science knowledge* that consisted of 20 identical multiple-choice items. The test was created by the research team along with teacher feedback and then was further developed in a validation study. The content was aligned with the passages in the GBLE along with the state curriculum and included both declarative and conceptual level items. For the purpose of analysis, the pretest of science knowledge was included as a measure of prior knowledge and a gain score (science posttest performance - science pretest performance) was created to indicate change in knowledge after playing the GBLE.

Students also completed three motivation measures that included *science self-efficacy*, the *Achievement Goals Questionnaire (AGQ),* and the *Perceived Interest Questionnaire (PIQ)*. Science self-efficacy $\alpha = .91$ was measured with 10 7-point Likert scale items (e.g., “Please indicate how certain you are that you can learn about ecosystems”). The AGQ was measured with 12 7-point Likert scale items that measured four factors of achievement goal orientation: mastery approach, mastery avoidance, performance approach, and performance avoidance [10]. For the purpose of analysis in this study only the performance approach ($\alpha = .79$) and mastery approach ($\alpha = .75$) factors were included. The PIQ [11] included 10 5-point Likert scale items ($\alpha = .95$) that measured student interest in the GBLE. A single-item measure of video game interest was also included that asked students how much they liked video games.

Students first completed the 20-item science knowledge test in addition to some other demographic and motivation questionnaires. The following week the students then began playing *Missing Monty* for approximately 5 weeks depending upon class schedule, typically engaging with the GBLE twice a week for 45 minutes at a time. Students navigated through the GBLE individually with the teacher’s role only to intervene for technical issues. In the week following gameplay students completed the science

knowledge test again as a post measure. *Missing Monty* allowed students to read texts and complete challenges at their own pace and, as a result, students' completion status varied.

During gameplay students visited various animal researchers, read informational texts (see Fig. 1), and completed knowledge, summary, and metacognitive monitoring challenges. They attempted to determine the source of the illness at WU by saving critical information and understanding gained from the text passages presented by the animal researchers. Periodically, they were also challenged to display their multiple-source understanding within the game context. These assessments were all presented by animal characters within the game-environments within a gamified context where students received badges depending upon their performance levels.

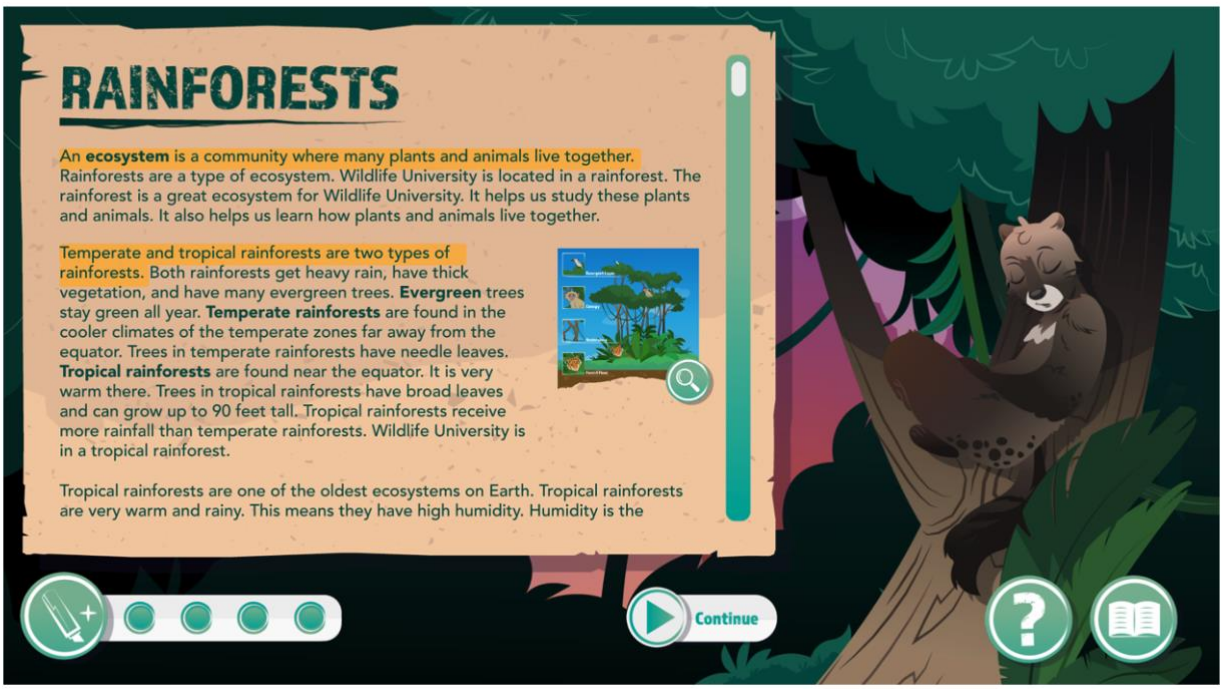

Figure 1. Text interaction in Missing Monty.

After completing *Missing Monty*, students were tasked with completing a transfer task activity outside of the game. The task was introduced by one of the game characters and was completed by students in an external Google Forms site. The transfer activity presented students with a dilemma, a fire spreading through an area of the savanna that had caused a number of animals to be relocated. Students were then tasked with the goal of relocating 14 African animals to one of three environments (see Fig. 2) with varying conditions while considering the needs and limitations of the animals. In considering the relocation site for each animal, students had to consider animal interactions including predator-prey relationships and competition for resources. Recognizing that some of the animals may be unfamiliar to students, character cards were created to provide information about each animal and their needs related to their diet and habitat as well as important aspects to consider in relation to their function within the greater ecosystem.

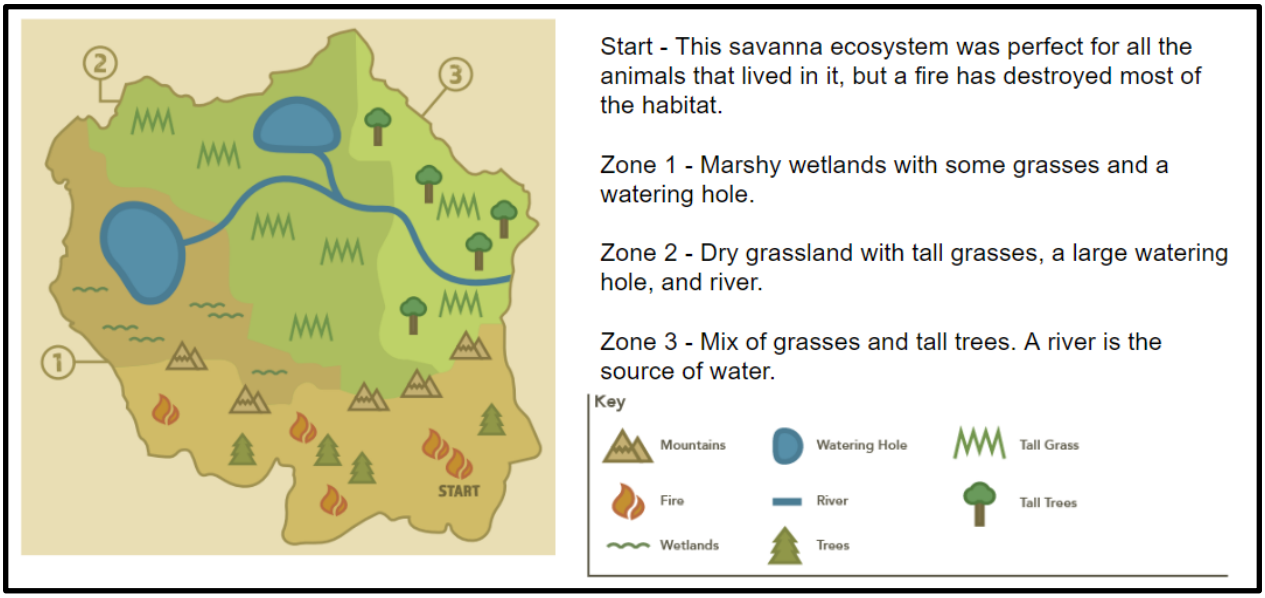

Figure 2. Relocation environments for transfer activity.

The goal in the design of the activity was for students to create a balanced ecosystem which consisted of an apex predator in each zone and an even distribution on the large herbivores to prevent territorial conflict. Only two of the 14 animals were able to be placed in any zone unconditionally (see Fig. 3) while another three had only a single habitat they could be placed in to meet all the requirements. The variation among answer combinations comes from the 'conditional yes' animal placements in the three zones. Some animals' placements (e.g., Yellow-billed Oxpecker) were dependent upon the presence of an herbivore (e.g., African Bush Elephant) in that same zone.

	A	B	C	D	E	F	G	H
1		Zone 1	Zone 2	Zone 3	Notes			
2	Thomson's Gazelle	N	Y	Y	Can't live in wetlands			
3	Rothschild's Giraffe	N	N	Y	Needs tall trees			
4	Yellow-billed Oxpecker	Yx	Yx	Yx	Needs herbivores			
5	Spotted Hyena	Yx	N	Yx	Can eat anything, no other predators			
6	Cape Buffalo	Yx	Yx	Y	Can live anywhere, can't live with hippo			
7	White-backed Vulture	Y	Y	Y	Can live anywhere			
8	Hippo	Yx	Yx	N	Needs watering hole, doesnt like other large animals (elephant, buffalo)			
9	African Sacred Ibis	Y	N	N	Needs shallow wetland			
10	African Wild Dog	Yx	N	Yx	Can live anywhere, no other predators			
11	African Bush Elephant	N	Yx	Y	Needs lots of grasses or trees for food, can't live with hippos			
12	Baboon	N	Y	Y	Need solid, dry ground			
13	Plains Zebra	Y	Y	Y	Can live anywhere			
14	Greater Flamingo	Y	N	N	Needs shallow wetland			
15	African Lion	N	Y	N	Needs tall grasses, no other predators			
16								
17	Yellow can go anywhere							
18	Blue can only go in one zone							

Figure 3. Scoring table for transfer task.

The task was designed to have multiple correct answers but with base considerations that were required. Answer combinations were validated by three staff at the North Carolina Museum of Natural Sciences. In sum, the task utilized information and skills students learned during the main *Missions with Monty* game to be abstracted within a different problem-solving context. This also simulated actual wildlife management approaches for animal relocation [12] as animals are often relocated for a multitude of reasons from population management to species reintroduction.

3 RESULTS

A single multiple regression analysis was performed to answer the two primary research questions: 1) the extent to which *Missing Monty* facilitated knowledge transfer and, 2) the extent to which motivational variables such as self-efficacy, goal-orientation, and interest contribute significant unique variance in predicting transfer over and above the impact of prior knowledge and knowledge gained within the GBLE. Therefore, performance on the transfer task was entered as the outcome variable with science pretest knowledge, post gameplay knowledge gain, science self-efficacy, game interest, performance approach, mastery approach, and videogame interest as predictors. Results revealed the model to be significant $F_{(7,96)} = 2.61$, $R^2 = .160$, $p = .016$. However, only science prior knowledge (b = .378, $p = .001$) and knowledge gains (b = .347, $p = .018$) were significant predictors. The effect of gain scores revealed the unique impact of *Missing Monty* above and beyond prior knowledge. Interestingly, none of the motivational variables were significant predictors.

Table 1. Multiple regression predicting transfer

	(*N* = 104)		
Predictors	*B*	*SE*	β
Science Prior Knowledge	.378**	.12	.344**
Science Knowledge Gain Score	.347*	.14	.243*
Self-Efficacy for Ecosystems	-.036	.03	-.118
Perceived Interest	-.032	.03	-.099
Performance Approach	-.191	.12	-.172
Mastery Approach	.181	.17	.13
Like Video Games	.004	.353	.001
R^2		.16	

Note. * < .05; ** < .01.

4 CONCLUSIONS

This study examined the impact of playing a GBLE and also motivational variables in predicting elementary students' performance on a dilemma-based transfer task. Learning outcomes associated with well-designed GBLEs are becoming more established [1][2], however transfer is still an open question in the research literature. A promising finding in the current study revealed that knowledge gains in the *Missing Monty* GBLE predicted transfer performance even after taking into account science prior knowledge. We attribute this finding to a number of elements of the *Missions with Monty* program including the strategy training undertaken within a framework that emphasizes SRL skills, the applied nature of the problem solving process in the game environment, the distributed practice over time with scaffolding provided by the animal characters, and immediate feedback that assisted students in monitoring their performance over time. The extent to which this finding generalizes across GBLEs, domains, and age groups is a question for further research. Similarly, the extent to which we can begin to identify critical elements of GBLEs that have a direct impact on transfer is also important for future studies.

Motivational variables failing to function as significant predictors of transfer replicates limited prior findings with GBLEs [9]. Further research is necessary to confirm these findings across different GBLEs as is consideration of motivational variables not measured in the current study. In addition, given the known importance of motivation to performance in traditional learning environments, future research would be wise to consider different indicators of motivation (e.g., trace data) [13] that might be more predictive of key outcome variables and less apt to be affected by limitations presented by self-report scales.

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