Connecting Student Information Resource Uses to Learning Outcomes in Guided Discovery-based Game Design

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Abstract
This research study investigates middle school and high school students' use of a wiki-based learning management system as a coordinating representation in the context of their guided discovery-based game design work. The study aims to (a) consider/validate the quality of Google Analytics page read data as a source of insight for research; (b) describe activity patterns; (c) investigate possible relationships between measured activity patterns and student learning outcomes; and (d) consider implications for practice, such as enhanced teacher training, program improvements, and even development of LMS information system diagnostic tools. Findings indicate positive relationships between resource uses and game quality outcome scores (a measure of student knowledge-building), across as several LMS curriculum page types including social media pages (Profile pages and Team pages) and information resource pages (Intro, Unit 3, and Actionscript tutorials). The research supports effectiveness of guided discovery-based learning in supporting knowledge-building, and holds local pragmatic implications for optimization of the e-learning system under investigation, as well as methodological and theoretical implications for the bridging fields of information and learning sciences.

Keywords: learning management system; discovery-based learning; game design; information-seeking; digital literacy; information literacy
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1 Introduction

As learning management system (LMS) content publishing platforms of commercial technology vendors become more widely available to middle school and high school teachers, school librarians and students, understanding discovery-based learning processes and outcomes involving inquiry and information-seeking becomes an increasingly important research question. "Discovery-based learning" experiences have been described as those in which learners are given a project task to complete over time (e.g., a complex problem or a project such as artifact creation), in which the task's completion must be supported by a process of learner-driven inquiry, resource use, problem-solving, and creation (Kirschner, Sweller & Clark, 2006). Often such complex activity occurs in teams. The extent of structure varies; more structured discovery-based learning has been termed "guided" discovery (e.g., Hmelo-Silver, Clark & Chinn, 2007; Reynolds & Hmelo-Silver, 2013). Examples of e-Learning platforms that facilitate guided discovery include corporate sites like Sakai, Blackboard and eCollege, as well as free and inexpensive content management services and social media including GoogleDocs, Google spreadsheets, Moodle, and Wikis. Researchers' investigation of discovery-based learning has implications for scholarship addressing questions of structure and agency during LMS uses, as well as pragmatic design principles, educator practice and measurement of student learning processes and outcomes.

LMS platforms and guided discovery learning contexts guide and structure learning, offering affordances such as teacher facilitation, peer support in collaboration, digital/print graphic organizers to frame and sequence their activities, certain software and hardware technologies to serve as the central locus for their creation, and a "coordinating representational" online space containing a range of information resources in variety of multimedia formats. Students may use these resources to support a variety of tasks.

This study investigates student engagement in guided discovery-based learning in the context of a game design program that employs a wiki-based learning management system as a key scaffold for student inquiry and information resource uses, online social media interactions and project management. Wikis are a form of participatory media that lend themselves to inquiry-based learning and the co-development of content in learning environments. They can serve both as a point of shared reference and shared production, and can also be built to contain information resources useful to the project at hand. While the use of Wikipedia is widely studied in educational contexts, with researchers addressing

questions focused on for instance how the authenticity of editing a large, public reference tool influences student participation and motivation (Forte & Bruckman, 2006), less explored is the use of wikis in the classroom as a design and coordination tool for long running projects. Such applications afford access to trace data such as page views, edits and uploads, that can be used for research and assessment purposes. The program being investigated has been implemented within middle and high schools in several U.S. states. Participating students engage in collaborative game design coursework for a full year daily, for credit and a grade within a formal, in-school class. The primary goal from the students' perspective is successful completion and online publishing of a functioning web game, which they also enter into an annual competition.

This study aims to better understand the ways in which students use different resources available in such platforms when provided ample time and freedom to engage in discovery, while also maintaining a discrete goal to complete the design and development of a playable digital web game by the end of their experience. The dataset comprises GoogleAnalytics page view results at the school level of analysis and for a range of different resource types on the LMS, for 23 schools in California and West Virginia, stemming from the 2012/2013 school year implementation. By comparing student uses of a variety of information and social media over time, the study demonstrates ways in which site metrics data can offer insight as to theoretical questions on structuring agential learning during guided discovery. The data also lend insight into implications for organizations and commercial entities offering such platforms, who may wish to a) develop reporting protocols to share with participating schools to encourage their use, and b) improve the usability of provided resources. The findings invite new practices and questions around data-driven decision-making practices for educators and librarians who use such services, as well. Methodological questions are also raised, as to how we study and measure phenomena across learning network structures such as this one, which occur at multiple levels of analysis, especially when outcomes data are opportunistically available. This exploratory study on school-level findings contributes insights to a larger program of research involving a multi-level analysis model combining data addressed herein, with other sources such as student and teacher surveys and questionnaires addressing a variety of psychological and attitudinal measures.

2 Background

The learning theories influencing the design of the game design program described below include social constructivism (Vygotsky 1962), and Constructionism (e.g., Papert and Harel 1991). Constructionism is a teaching philosophy and framework for learning and educative action (DiSessa and Cobb 2004) that builds upon Vygotsky's (1962) social constructivist theory and Piaget's constructivist theory. In Constructionist learning, students engage in conscious construction of a technologically mediated computational artifact in a workshop-style group educational environment (Papert and Harel 1991). This approach holds that individuals learn best when mobilizing their entire selves in a personally meaningful pursuit while sensing that their work is valued as part of a larger enterprise (Barron and Darling-Hammond 2008; Stager 2001). Aligning with social constructivism, Constructionist interventions are designed to facilitate learners' building of knowledge socially through dialogue and interaction, rather than by receiving it in a top-down way from a sole instructor and a print text. It adds computational creation of an artifact through programming as a key element. Overall, learning occurs through guided discovery -- through peers' interactions with one another, material resources (in this case, an online LMS and software), a workshop-based in-person setting, and an expert mentor (Papert and Harel 1991).

The literature on knowledge-building (e.g., Scardamalia, 2002) is related to Constructionism and is also a useful perspective to highlight, given its relevance to wikis for education. Knowledge-building addresses how learning contexts can be designed to facilitate students' own building of theories and conceptual artifacts. A primary goal of this approach is to engage learners in sustained collaborative inquiry and to provide them with opportunities to work creatively with ideas (Chan, 2013). "Knowledge-sharing" has been distinguished from knowledge-building in that knowledge-sharing involves the flow of information and knowledge co-construction (development of shared understanding), whereas in knowledge-building, the goal is to collaboratively construct *new ideas* through discourse, in resolution of authentic problems (Van Aalst, 2009). While in knowledge-building the product of student collaborative engagement and discourse is often a conceptual artifact or set of ideas represented in speech or written documentation, in Constructionism, the productive outcome comprises both conceptual *and* actual concrete computational artifacts, such as a game (Reynolds & Hmelo-Silver, 2013).

Scardamalia (2002) proposes twelve principles as conditions of knowledge-building interventions, presented in Table 9.1. Linkages have been identified among these principles, to the conditions of Constructionist interventions, and to the instructional design strategies employed in Globaloria (Reynolds & Hmelo-Silver, 2013). Overall, by involving students in a workshop-based blended learning classroom setting, and providing a host of wiki-based LMS resources, Globaloria aims to actualize the knowledge-building conditions described below in student learning.

Knowledge-building (Scardamalia, 2002)
– *Real ideas and authentic problems.* In classroom knowledge-building community, learners are concerned with understanding, based on real problems in the real world.
– *Improvable ideas.* Students' ideas are regarded as improvable objects.
– *Idea diversity.* In the classroom, the diversity of ideas raised by students is necessary.
– *Rise above.* Through a sustained improvement of ideas and understanding, students create higher-level concepts.
– *Epistemic agency.* Students themselves find their way in order to advance.
– *Community knowledge, collective responsibility.* Students' contribution to improving their collective knowledge in the classroom is the primary purpose of the Knowledge-building classroom.
– *Democratizing knowledge.* All individuals are invited to contribute to the knowledge advancement in the classroom.
– *Symmetric knowledge advancement.* A goal for Knowledge-building communities is to have individuals and organizations actively working to provide a reciprocal advance of their knowledge.
– *Pervasive Knowledge-building.* All students contribute to collective Knowledge-building.
– *Constructive uses of authoritative sources.* All members, including the teacher, sustain inquiry as a natural approach to support their understanding.
– *Knowledge-building discourse.* Students are engaged in discourse to share with each other, and to improve the knowledge advancement in the classroom.
– *Concurrent, embedded, and transformative assessment.* Students take a global view of their understanding, then decide how to approach their assessments. They create and engage in assessments in a variety of ways.

Table 9.1: Knowledge-building

2.1 Critiques

Debates have emerged in the learning sciences literature around the efficacy of “discovery-based” constructionist and inquiry-based approaches for the full diversity of learners. A widely cited article in the journal *Educational Psychology* by Kirschner et al. (2006) strongly dismissed discovery-based approaches as ineffectual, due to a lack of structure in autonomy-supportive inquiry-based learning contexts, and excessive cognitive load that over-taxes the working memory needed to learn the core material (e.g. introductory computer programming in the case of the program investigated herein). Kirschner et al. (2006) suggest that the emphasis on self-guided learning across time, and the extra task of seeking out informational resources can lead to frustration and de-motivation in students, impeding learning progress rather than supporting it. The article prompted direct responses in the literature counter-arguing that discovery-based interventions involving inquiry are not entirely unguided, but in fact reflect varying extents of structure. Hmelo-Silver et al. (2007) point out that even in learner-centered interventions, student work is structured by systems and/or expert guides and may be better described as “guided” discovery.

Scaffolds and instructional contexts supporting inquiry-based learning can and should be designed to minimize cognitive load effects. A benefit of inquiry-based learning is its focus on student-centered inquiry to meet individualized and varying student needs at their level, in contrast to more highly structured, short-term and single-timeframe cognitive approaches to problem set design, which presume that learners share common cognitive processes that can be activated with a single, highly structured instructional context that is uniform across all learners. Moreover, in further support of inquiry-based approaches, there is a growing research evidence base indicating that students do not necessarily need to be successful in a given learning activity proximally to gain an advantage distally. The research on the “productive failure” phenomenon captures evidence that less-structured problem contexts can lead to more long-standing positive learning outcomes because such contexts guide people in understanding the deep structure of problems, not simply their correct solutions (e.g. Kapur 2006, 2008; Kapur and Kinzer

2009). Other research studies indicate that a learner's level of prior expertise, in the core knowledge domain as well as in the supporting inquiry processes, i.e. their status as novices versus experts, is also a salient factor to consider when designing instructional supports (National Research Council 2000, p. 29-50). These theoretical perspectives inform the research questions for this study (presented in summary below).

2.2 Wikis as a Learning Management System Platform.

As a form of participatory media, wikis can support student knowledge-building, serving as both a point of shared reference, and shared production among students who engage freely in cultivating a base of online content. If designed to do so, such environments can add structure to student project-based work (e.g., creation of a digital artifact such as a game) by offering a host of pre-selected and pre-stocked, curated information resources, assignments and activities. Salomon, Perkins & Globerson (1991) describe such a resource as a "coordinating representation" -- a type of scaffolding support in which "an intelligent technology can undertake a significant part of the cognitive process that otherwise would have to be managed by the person." Among undergraduates, wikis have been found effective in supporting project-based work, making it easier for actors to work in parallel, multitask and make 'common sense' of the situation and how to proceed with the action (Larussen & Alterman, 2009, p. 375).

The wiki-based LMS in the game design program studied serves this role as a coordinating representation for middle school and high school students, which is novel for this age group in the knowledge domain of computer science education and computational thinking. The design and deployment requires thoughtful planning to curate the resources, activities and assignments, and to format the site navigation for students' optimal uses. However, once an initial implementation for a given course is developed, this implementation can be refined and iterated over many cycles as the course / module is re-taught and the educator observes student experiences with it. Iterative design is a key principle. In addition, the MediaWiki technology platform affords teachers with automatic reporting, allowing them to monitor and assess students' ongoing digital work activity, tracking site usage history, page edits, and file uploads. These auto-generated reports in the system can be coupled with the addition of GoogleAnalytics page read data options, facilitating evidence-based practice by educators who can pull reports and make adjustments to in-class scheduling and instruction on-the-fly given data results.

2.3 Game Design Program Features

The game design curriculum and year-long experience for students we study offers a sequence of activity units and course content structuring the learning. In the first half of the 2012/2013 school year, students worked individually on Units 1-2, and in semester 2, the assignment Units 3-4 move to teamwork. Student engagement in the latter phase becomes more self-paced, emergent and open. During this time, teachers must differentiate instruction to help guide students and teams as they engage more so in inquiry activity with the wiki LMS resources for learning to program and code. Students used Flash as their game production software. The LMS contains these features.

- *Information resources* including curriculum, assignments, schedules, syllabi, and in-depth video- and text-based tutorials for game design and programming.
- *Social media features* including profile, project and team pages that facilitate communication among classmates as well as collaboration through sharing and discussion of game assets. These features include project management affordances such as "Project Pages" and "Team Pages" enabling uploading, sharing, and archiving of in-progress and final game artifacts, which are uploaded as files and organized on these page types, requiring students to engage versioning and file naming conventions, and descriptive text situating the digital assets they upload and publish on these pages.

We expect that in the context of discovery-based learning, students will vary in their extent of use of these resources, and we aim to explore this variation using GoogleAnalytics site metrics across time, investigating ways in which patterns of resource uses vary across time and across schools, and ways in which certain patterns may be linked to student knowledge-building. The dataset available is at the *school level of aggregation only*, however, which poses limitations given that individual-level resource uses are hidden within class-wide totals. Therefore, in the school level data, a high standard deviation for mean page views of a given resource, across all schools and all time, might indicate school-level differences in curriculum implementation, effective class management or other varying teacher actions that led to the difference in resource uses. Time is also of interest in this analysis; for instance we might expect frequencies for Profile pages views, Intro and Unit 1 page views to be higher in the first half of the school

year, and use of curriculum resources for more advanced game design to occur later on. Patterns of variation on types of uses across time are therefore explored.

2.3.1 Research Questions.

1. To what extent do student uses of LMS resources vary by resource type, by school, and across time?
2. In what ways do students' patterns of use of different types of information resources across time appear to be related to learning outcomes?

3 Method

This study draws upon click stream (Google Analytics) page read data from the wiki-based LMS, for all full-year locations.

3.1 Data Source Description, Dataset 1

Every page on the project LMS is set up to be mined by Google Analytics**.** Page view reports were run by school, in aggregate, and across 5 time increments: 08/01/2012-09/30/12; 10/01/2012-11/30/12; 12/01/2012-01/31/13; 02/01/2013-03/31/13; 04/01/2013-06/25/13. We exported the data from Google Analytics as Excel files, merging them into a master spreadsheet. **We calculated standardized metrics, dividing total page views by the N of student participants at that location for any given resource, to give a metric of average page views per student per year for the given resource.** Some students participated for half a year and others for a full year (and at some schools, there were mixed but we knew who in the mixed school was full versus half). Thus when we "standardized" our data, half-year students were counted as .5 whereas full year students were counted as 1, thus our standardization procedure accounts for this time difference in the denominator, for the page view standardized metrics (for half, full, and mixed duration schools).

Social Media Features. Profile pages are those pages editable by students, on which students post images and information about themselves to create an initial online identity. Profile pages do not contain game files or game work. *Project* pages are those pages editable by students, on which students post their individual-level hidden object game files and game design work from the first half of the school year. In contrast, *Team* pages are those pages editable by all members of student teams, which serve as the locus of team activity, where they post shared game files, design plans, and text-based communications and discussions about the ongoing progress of their game.

Information Resources: Curriculum Unit Pages. Curriculum unit pages are *not* editable by students, and contain curriculum content, assignments, tutorials, and informational copy, video and sample code to support game design learning. They include the following units: Intro, Wiki Tools, Units 1-4, and Actionscript Tutorials. Each unit contains at least 5 URLs of resources. We aggregated all URLs under a given unit, and standardized the data.

3.2 Game Evaluation Outcomes, Dataset 2

We define "game" as: a file that goes beyond a mere image, to include some level of interactivity, in which, at minimum, the file provides response to the player, based on a player action. Defining a "game" at this minimal level of interactivity allows us to code the full range of variability in the game file quality created by students, basic to advanced. The format of the game files students post online include both .SWF (Small Web Format / Shockwave Flash) and the .FLA project file format. The final coding scheme enables evaluation of Actionscript programming codes that could reasonably be expected from introductory game design students (1=present, 0=absent), and, evaluation of design attributes built into the game (visual and sound design elements, game play experience, concept development, genre) (1=Not present / insufficient representation; 2=basic / introductory representation; 3=well-developed representation). The team scores ranged from 16 to 61. To test inter-coder reliability, we computed the kappas for each section of the coding scheme: Actionscript programming evaluation, 0.85; Visual and sound design evaluation, 0.81; Game play experience evaluation, 0.87; Concept development evaluation, 0.75.

3.3 Participants

Google Analytics page read data were aggregated for a sample of students who participated in the game design, during the 2012/2013 school year. The data represents user actions of a total of 625

students in grades 6-12 in 23 public schools (3 California, 20 West Virginia), who participated for either a full year, one semester, or a mixed set (some students full, some students one-semester). Students created a total of 214 games. At 5 schools (CapHS, MVHS, OvHS, NMarHS, PhBHS) only a small number of students created final games. Average team game score descriptive data across all schools are included in Table 1 below. It is important to note the limitation that at 3 schools, a larger proportion of students did not create games. Thus, the mean team game score as a representative knowledge outcome variable at the school level at these 3 schools holds a lesser extent of validity than at schools in which the majority of students created a game. *As such, we omitted the 3 schools CA:OvHS, CapHS and MVHS from the bivariate relationship results*. For Duration, 3=Full Year, 2=Mixed, 1=Single-semester.

4 Results.

Descriptive statistics in Table 1 indicate that the majority of students participated in full-year programs. The N of students and corresponding N of games varied substantially. At 3 locations (ChapHS, HurHS, MonHS), students created games as individuals rather than teams, proceeding through the second semester curriculum working solo.

Table 1. Participant Schools, Sorted by Avg. Team Game Score (High to Low)

School	N of students	N of games	Duration	Average team game score
*CA: OvHS**	*67*	*1*	*3*	*57.00*
*CapHS**	*45*	*4*	*3*	*47.75*
GeonHS	56	25	3	45.26
TyVHS	20	10	2	42.91
HurHS	41	41	2	42.15
ChapHS	5	4	3	40.50
UnHS	7	3	3	39.57
BuHS	2	1	1	39.00
GrEHS	8	4	3	38.25
SanMS	35	16	3	38.18
ElsMS	49	18	3	37.56
CA: AdVStem	56	20	3	36.37
CA: HerMS	9	4	3	36.00
PhBHS	47	8	2	35.92
LogMS	10	3	3	34.33
WoodHS	17	8	1	34.24
MonHS	8	8	2	28.42
TCTCHS	18	7	3	24.33
CharlMS	18	8	3	23.75
NMarHS	40	4	2	23.28
ChapMS	36	11	3	21.61
RivHS	6	4	3	20.00
*MVHS**	*25*	*2*	*3*	*18.55*
	625	**214**		

**omitted*

Table 2 presents an overview of the descriptive statistics for the average game score across locations included in the final dataset.

Table 2. Average team game score (out of 61 possible 'points')

	N	Minimum	Maximum	Mean	Std. Deviation
Average Game Score	20	20	45.26	34.08	7.7

Descriptive statistics in Table 3 indicate the means and standard deviations for the following information resource types in the curriculum and social media pages, across the 5 timeframes. Curriculum page views include Intro, Units 1-4, and Actionscript tutorials. Social media page views include Profile, Project, and Team pages. Findings indicate that for Intro, Unit 1 and Unit 2, on average, students engaged in curriculum uses for these units more so in the earlier timeframes. While students engaged substantially less frequently in use of Units 3 and 4, their uses in aggregate appear to have occurred more so in the latter timeframes. Actionscript tutorials represented a broad array of resources and their uses occurred across all timeframes. For the social media pages, Profile page views were apparently higher in the earlier timeframes whereas Project and Team page views (again while lower than Profile page views apparently) were higher in the latter timeframes. Team pages were utilized across the 5 timeframes whereas Project pages were utilized more so in the latter on average. Standard deviations indicate variation among schools for all units.

Table 3. Standardized Page Views	N of Schools	Min	Max	Mean	Std. Deviation
Intro T1	20	3.8	163.5	92.7	37.3
Intro T2	20	2.8	199.4	77.9	44.9
Intro T3	20	15.6	130.6	62.6	31.9
Intro T4	20	6.0	207.3	79.9	54.1
Intro T5	20	12.6	132.1	64.5	33.9
Unit 1 T1	20	1.5	61.8	17.2	14.4
Unit 1 T2	20	0.0	5.0	1.3	1.7
Unit 1 T3	20	0.0	29.0	3.0	6.9
Unit 1 T4	20	0.0	22.9	2.5	5.5
Unit 1 T5	20	0.0	0.5	0.2	0.2
Unit 2 T1	20	1.6	38.9	16.8	10.3
Unit 2 T2	20	0.0	39.6	10.1	9.5
Unit 2 T3	20	0.3	29.0	4.7	7.5
Unit 2 T4	20	0.3	30.6	5.5	8.3
Unit 2 T5	20	0.0	3.8	1.0	0.9
Unit 3 T1	20	0.3	14.9	2.7	4.0
Unit 3 T2	20	0.0	45.0	9.2	11.4
Unit 3 T3	20	0.2	30.4	7.9	8.2
Unit 3 T4	20	0.9	49.6	12.8	13.5
Unit 3 T5	20	0.2	18.2	4.9	5.1
Unit 4 T1	20	0.0	4.0	0.3	0.9
Unit 4 T2	20	0.0	2.0	0.3	0.5
Unit 4 T3	20	0.0	6.4	0.5	1.4
Unit 4 T4	20	0.0	0.6	0.2	0.2
Unit 4 T5	20	0.0	10.5	1.0	2.3
Actionscript Tutorials T1	20	1.3	342.2	186.3	97.9
Actionscript Tutorials T2	20	1.8	380.1	124.6	90.6

Actionscript Tutorials T3	20	19.6	273.0	98.6	64.4
Actionscript Tutorials T4	20	18.9	261.7	116.2	74.5
Actionscript Tutorials T5	20	10.0	196.8	76.5	46.3
Profile Pages T1	20	0.0	88.9	37.6	23.3
Profile Pages T2	20	0.0	90.9	45.9	26.8
Profile Pages T3	20	0.9	87.4	24.6	17.4
Profile Pages T4	20	4.0	119.8	37.8	37.5
Profile Pages T5	20	2.8	66.8	20.7	17.9
Project Pages T1	20	0.0	23.6	1.8	5.7
Project Pages T2	20	0.0	63.6	12.1	21.0
Project Pages T3	20	0.0	46.7	15.0	17.5
Project Pages T4	20	0.0	69.7	23.3	16.8
Project Pages T5	20	0.0	111.3	27.6	25.4
Team Pages T1	20	3.8	163.5	92.7	37.3
Team Pages T2	20	2.8	199.4	77.9	44.9
Team Pages T3	20	15.6	130.6	62.6	31.9
Team Pages T4	20	6.0	207.3	79.9	54.1
Team Pages T5	20	12.6	132.1	64.5	33.9

Rather than include the data for all 5 timeframes for each curriculum unit in the bivariate analysis, it was decided to prioritize the time frame for each curriculum type that reflected the highest frequency of engagement. Thus, Table 4 presents the bivariate results for just these select highest-frequency timeframes (per Table 3 means). The exception was for Actionscript tutorials in which we selected T4 because it was expected that the exploratory work engaged by students in T1 appeared less predictive of latter processes and outcomes than the activity in T4 (second semester, in which students engaged most in programming help-seeking towards the team project representing the outcome variable). For Units 3 and 4, parsimoniously, the higher N of standardized page views for engagement appears in Times 4 and 5. Profile page views appeared highest in T2, Project pages in T5. For Team pages we chose T4 even though T1 appeared higher, for the same rationale as the Actionscript Tutorials. Bivariate results are as follows.

Table 4. PVs X Program Duration X Game Score X % Free and Reduced Lunch (proxy for SES) (Pearson Correlation Coefficients)

	Prog, Dur-ation	Avg. Game Score	% Free/ Red. Lunch	Intro PVs	Unit 1 PVs	Unit 2 PVs	Unit 3 PVs	Unit 4 PVs	Action -script Tut.	Profile PVs	Project PVs
Prog. Duration	1										
Avg. Game Score	-0.12	1									
% Free/Red. Lunch	0.01	-0.28	1								
Intro PVs	0.44**	0.00	-0.09	1							
Unit 1 PVs	0.28	-0.41*	0.12	0.38*	1						
Unit 2 PVs	0.14	0.15	-0.31	.46**	.46**	1					
Unit 3 PVs	-0.36	0.13	-0.13	.37*	0.20	.29	1				
Unit 4 PVs	-0.16	0.33	-0.30	.20	-0.09	0.33	0.65***	1			
Act-scpt Tut	0.12	.18	-0.10	.39*	0.03	0.09	0.40*	.27	1		
Profile PVs	0.32	0.01	-0.11	.78***	0.35	0.34	0.48**	.39*	0.47**	1	
Project PVs	-0.36	0.37	-0.22	.03	-0.24	0.20	0.27	0.60***	-0.03	0.29	1
Team PVs	0.17	.39*	-0.19	.51**	0.06	.29*	.53**	.66**	.52**	0.47*	.09

*Correlation significant at 0.1 level (2-tailed); **Correlation significant at 0.05 level (2-tailed) *** Correlation significant at 0.01 level (2-tailed)

Findings for the bivariate analysis indicate that the greater the project duration, the more the Intro page views. Intro page views and Team page views were correlated with the greatest number of other curriculum variables. Unit 2 was correlated with both Intro and Unit 1 page views but not any of the other curriculum types. Intro page views showed a strong correlation with Profile page views in particular whereas Team page views showed a strong correlation with Unit 4 page views. Interestingly, Unit 1 page views were negatively correlated with game evaluation outcomes whereas Team page views showed a positive correlation with game evaluation outcomes. It may be that schools focusing on Unit 1 became "stuck" in this modality whereas students who used the team page showed higher engagement in team game creation. Actionscript tutorials were highly correlated with Project and Team page views as well. Project and Team pages represented the locus for student creation and uploading of team game artifacts, representing both programming and design activity, and the requisite expertise. These page types appeared more strongly correlated to Units 3 and 4 than the earlier curriculum units. Overall, the variables of Intro, Unit 1, Unit 2 and Profile page views share correlations among one another, whereas the variables of Units 3, 4, Actionscript tutorials, Project and Team pages share inter-relatedness. In future work we might consider factor analyzing these curriculum types, as "Less advanced" and "More advanced" curriculum activities.

Recall that the researcher decision was made to analyze only the resource use timeframe with the highest mean page views for any given resource type (e.g., for Unit 3, the timeframe 4 data were used in the bivariate analysis reported in Table 4 above). Therefore, in order to more fully consider the relationships among resource uses across timeframes and learning outcome scores, post-hoc analysis was conducted using the standardized page views for each resource, across all timeframe (e.g., Intro, T1-5; Unit 1, T1-5, etc.). Post hoc findings indicate there were several more positive and statistically significant relationships between resource use types and outcome scores. Specifically, Intro T5 (r=.52, p<.05), Unit 3 T2 (r=.45, p<.05), Actionscript Tutorials T3 and T5 (r=.38, p<.05; r=.38, p<.1), Profile T5 (r=.45, p<.05), and Team T2-T5 (r=.59, p<.01; r=.57, p<.01, r=.39, p<.1; r=.51, p<.05) were all positively correlated and statistically significant. Further, Unit 4, T4 and 5 had r values that were very close to statistical significance at the p<.1 level, suggesting that significance might be achieved with a higher N of schools, warranting further investigation.

5 Discussion.

As a "coordinating representation," the wiki LMS aims to help students orient and make sense of their game design activity. As for the social media pages on the wiki LMS, the Profile, Project and Team pages are the locus for coordinating students' active design and programming work, and where they archive, present and share code. Profile pages are used early in the curriculum to establish their online identity; Project and Team pages relate more so to actual game design and represent more substantive Flash game design activity. The social media page view findings indicate that on the whole, students visited their profile pages more so than the more productivity-oriented project pages or team pages across this school year. Profile pages used in latter phases positively contribute to game scores, as do team page views across T2-T5. It appears the social media page views are helpful in students' knowledge-building.

Findings for page views to the non-editable curricular unit pages containing informational resources indicate that overall, students appear to engage much more so with topics residing earlier in the curriculum sequence (Intro, Wiki Tools, Unit 1, Unit 2) than later (Units 3, 4, Actionscript Tutorials). It appears that most schools make it through the first few units, and drop off in their extent of utilizing the curriculum resources in the latter stages of the program. At the school with the highest Unit 4 page findings, the activity still appears somewhat minimal. While the latter units had lower SDs because of the lower page views overall, the high standard deviation results for the earlier curriculum units with greater page views indicate that for those earlier units, data points across schools appear spread over a larger range, indicating that schools varied in their extent of use of the earlier units. That is, only some schools demonstrated higher use of the earlier units; not all.

Interestingly, the unit with the highest use across time was the Intro unit, which appears to be of most value, as the course is presently being taught and experienced. The Intro unit contains the Game Gallery, which is the area that features all existing and past completed games in Globaloria. It seems that many students may be playing and reviewing existing game content, and comparing their projects to these exemplars. Intro use in T5, contributes positively to game scores, perhaps indicating students' return to the beginning materials and the game gallery, while polishing their own final games.

The post hoc analyses offer greater support for a general hypothesis that resource uses contribute to student learning for some curriculum units, in that Unit 3 uses were found in the post hoc analysis to contribute positively, as well as Actionscript tutorials in T3 and T5. The two close-to-significant results for Unit 4 warrants further investigation and may suggest Unit 4 contributes, too, when it is actually accessed (that is, when schools and students get that far). Overall, results suggest that for those who do use the curriculum material, its use can be valuable in their knowledge-building. The results offer justification for testing the hypothesis about resource uses further, for instance in multi-level analysis occurring as follow-up research. More research is needed to understand the school-level variation in resource uses. That is, why are some schools not using the resources as extensively as others?

The findings invite greater investigation into teacher and student information literacy practices around resource uses, teacher expertise, class management, etc. These resource use and social media page data, at the descriptive frequency level, also offer an imprint of student activity that may serve to be useful for formative assessment. The data suggest that students may need greater scaffolding for information literacy, to improve the resource uses (e.g., searching online, greater orientation to the structure of the wiki LMS and its resources, and perseverance through unanswered questions). These results are supported by Reynolds (2016). These results have implications for information literacy instruction, especially as blended learning instructional models are more readily adopted by schools. Individual differences and team level factors may influence the extent of "resourcefulness" a student evidences. For instance, Reynolds & Chiu (2012) report upon the relationship between intrinsic motivation and student learning outcomes that was found in a large N survey dataset in the school year prior to this one. The research invites questions around whether and how such discovery-based contexts can better support students who are less self-determined and intrinsically oriented. The question stands as to how inquiry or discovery-based learning contexts are effective for such students. More research is underway by the author to qualitatively investigate resource uses and inquiry practices that are emergent when limited information literacy instruction is proffered.

Limitations. Also, while such wiki LMS – generated behavioral trace data sheds light on resource use patterns, such data have limitations in the insights they may offer. The following phenomena in observed during case study site visits and with regard to the page view site metrics indicate the need for caution. These and other limitations must be considered in the work moving forward. (1) Lack of activity on the wiki may belie significant productive activity in class, such as their collaborative engagement, that

may be more significantly influencing student learning and outcomes. (2) It has been observed that on (rare) occasions, students log in to the wiki as a user other than themselves, and/or sharing computers without changing the login credentials to their own username as they make edits or uploads, which, while data are aggregated at the class level, pose no problems, but would do so if aiming for an individual analysis. (4) Further, we can't know whether just a single individual or small N of individuals at a location are accounting for a majority of the page views. The availability of the page read data at the location (school) level is a clear limitation that obfuscates the findings somewhat, and presents limitations in what we might infer from these data alone.

6 Conclusion

More research is needed to validate the observed patterns of relationships and inferences drawn on the linkages between resource uses and outcomes. The availability of resource use data at the school-level only led us to investigate its possible observed associations to the game evaluation data when rolled up to the class level as averages. A range of context-level differences might explain the resource use variation we saw, e.g., teacher practices. There is also likely to be team- and student-level variation embedded within school-level phenomena. Given the patterns observed at the school level of analysis, though, when available, we will use the school level resource use data in multilevel analysis statistical models investigating the contribution of phenomena at the community, school, teacher, student team, student individual levels, towards student outcomes. Research such as this can shed light into ways in which phenomena at varying levels influence outcomes, to greater and lesser degrees. We will also be employing individual and team level data to investigate whether class level effects remain when individual and team level resource use differences are accounted for. Such research will help us to see at what level we should emphasize placement of revised instructional interventions to improve student experiences and learning. If the class-level resource uses demonstrate stronger associations to outcomes whereas individual or team level level resource uses do not, we know that context factors may be at play; if both contribute, then it will lend credence to the idea that both educators and students need support in their information literacy. Such a model can contribute to the ongoing debates regarding constructivist and Constructionist and discovery-based learning. The observed patterns of relationships presented here overall support the inclusion of such data in the multi-level analysis models (e.g., that conducted in Reynolds & Chiu, 2012, and presently under expansion in more recent work).

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