Understanding and Measuring Student Inquiry and Resource Use Processes, and their Contribution to Outcomes, in "Guided Discovery-Based" Learning

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ABSTRACT

This research study investigates middle school and high school students' use of a wiki-based e-learning platform 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 wiki trace data and 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; (d) consider implications for practice, such as enhanced teacher training, program improvements, and even development of LMS information system diagnostic tools. The research holds local pragmatic implications for optimization of the e-learning system under investigation, as well as methodological and design implications for the bridging fields of information and learning sciences.

Keywords

Learning analytics, game design, guided discovery based learning, information literacy, Constructionism, social constructivism, guided inquiry, collaborative information-seeking

1. INTRODUCTION

"Discovery-based learning" experiences are 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), and 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). Guided discovery based learning is discussed in the educational research discipline of the "learning sciences," under the theoretical influence of social constructivism, and the methodological paradigm of "design-based research."

Most discovery-based learning research occurring in the learning sciences discipline focuses on designed learning interventions employing inquiry processes among learners as an instructional feature, in contrast to information science research on naturalistic search. Theoretical models in information science relating to guided discovery include Kuhlthau, Maniotes & Caspari's "guided inquiry" and "guided inquiry design" models, as well as Paul and Morris' (2011) investigation of sense-making during collaborative inquiry and web search. Sense-making can be seen as a learning process in and of itself.

Instructional contexts of inquiry and search are perfectly valid research domains for information science and this new "Searching as Learning" grouping of scholars, especially given the growing use of information systems in such contexts, and their deployment in library and school library settings and programs (physical, programmatic and digital), which require design.

Instructional affordances and scaffolds that guide learners' inquiry and discovery may include teacher facilitation, peer support in collaboration, digital/print graphic organizers to frame and sequence their activities, curricular sequencing, worked examples of problems, certain software and hardware technologies, online information resources in variety of multimedia formats, and other web tools and web services, e.g., social media and learning management systems. In such learning experiences, the inquiry activity may be driven by multiple tasks. For instance, in the case of a project-based work context, the inquiry might occur in service to (a) the procedural tasks of programming of the artifact (e.g., problem-solving the technical mechanics) and/or, (b) the content or message of the artifact (e.g., curricular content such as science as the knowledge domain). Different inquiry strategies and processes may therefore be required and/or employed (Reynolds, Baik, Li, 2013).

However, debates still ensue regarding the effectiveness of these inquiry based learning contexts. Critiques and refutations have issued in the literature around considerations of structure, cognitive load, and ways in which inquiry and collaboration can contribute to, and/or detract from, student learning in the primary knowledge domain (e.g., Kirschner, Sweller & Clark, 2006; Hmelo-Silver, Duncan & Chinn, 2006). Critics argue against cognitively distracting learners with inquiry and resource use processes *in addition to*, for instance, learning basic computer science principles. However, while debates ensue at theoretical levels, thus far, relatively little empirical work exists describing learners' *emergent inquiry strategies* in such contexts, their search procedures, resource use preferences, successes and failures (and the possibility of failures' contribution to successes), and learning outcomes, in "blended" learning experiences employing guided discovery. This is especially true at the K-12 level because to-date, students in schools have rarely been afforded the autonomy or opportunity to engage longitudinally in such open-ended exploratory learning with an eclectic array of self-sought resources (but this is quickly changing with the digitization of curricular content and development of online distribution channels, aggressively underway by publishers).

More research is needed to understand the dynamic among inquiry and collaboration activities in these settings, and ways in which social constructivist learning may support, or hinder, learning outcomes. Information sciences perspectives and insights

on inquiry, collaborative information-seeking, and sense-making can contribute to learning sciences; likewise, learning sciences debates around designing an intervention, structure and scaffolding can contribute to information sciences research that investigates learning phenomena.

2. Present Study

Thus, the present study seeks to better understand student inquiry and collaboration practices in the context of a guided discovery-based learning program focused on game design, called Globaloria. In this program, which embodies the principles of social constructivism, Constructionism and distributed cognition (Harel & Papert, 1991; Salomon, 1997), a game design curriculum and learning management system is deployed in middle schools and high schools in several U.S. states, through involvement of a non-profit who developed the initiative. Participating students engage in collaborative game design activity within a formal, in-school class, daily, for credit and a grade for an entire year. 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. The program has 6 dimensions of learning objectives (Reynolds & Harel, 2009; Reynolds, 2014).

Student engagement is supported by informational content and resources available on an e-learning platform (or learning management system [LMS]). Salomon, Perkins & Globerson (1991) describe such resources as a "coordinating representation," which is a type of scaffolding support in which "an intelligent technology that can undertake a significant part of the cognitive process that otherwise would have to be managed by the person." Larussen & Alterman (2009) found that wikis can be used to support 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 (p. 375). The wiki-based LMS in Globaloria serves this role.

The research questions guiding this study are:

1. How do students engage in inquiry to support game design in Globaloria?

2. How does information resource use relate to actual learning in this social constructivist learning context?

2.1 Method

In the program under investigation, students follow a sequence of activities and course content. In the first half of the school year, they work individually, thus user actions can be mapped more directly to the syllabus sequence as they gain introductory game design expertise. In the second half, the work is less structured, moves to teamwork, and the engagement and problem-solving become more emergent and open. During this time, teachers must differentiate instruction to help guide the varying teams in their goals and progress and as the students engage more in inquiry activity to answer their in situ questions.

The present study draws on two data sources for the 2012/2013 school year. The first is click stream data (Google Analytics) from the wiki-based LMS, for all full-year locations. The second is video observational data of student work processes for six teams of students from a school in Texas.

2.1.1 Participants, Dataset 1

For the click stream data results on resource uses, Google Analytics page read data were aggregated for a sample of students who participated in the Globaloria Game Design Program, during the 2012/2013 school year. The data represents user actions of a total of 708 students in grades 6-12 in 31 rural West Virginia public schools participated for a full school year, in Globaloria. In these reported results, we omit single semester and mixed group schools, and thus the findings below represent the 21 full year schools only, for a total of 455 students, who created a total of 340 individual hidden object games, and 93 team games.

2.1.2 Data Source Description, Dataset 1

Every page on the Globaloria project LMS is set up to be mined by Google Analytics**.**

Profile, Project and Team Pages. 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 hidden object game files and individual-level game design work from the first half of the school year. Team pages are those pages editable by students, which serve as the locus of team activity, on which all team members post shared game files, and communicate about the ongoing progress of their game.

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. Here we report page view clickstream data retrieved from the Google Analytics reporting tool, for profile, project, team, and curriculum pages. We aggregated all URLs under a given unit, and standardized the data. Page view reports were run by school, in aggregate, and across the 5 time increments below. We exported the data as excel files, merging them into a master spreadsheet. **We calculated standardized metrics, dividing total page views by the N of students at that location, to give a metric of average page views per student per year for the given resource**, and to facilitate more "apples to apples" comparison in the Excel tables that follow.

2.1.3 Participants, Dataset 2

Observational video footage from site visits at one school in TX were conducted during a week in March, 2013 and a week in May, 2013 (~6 hours of footage per team per week). We followed 2 teams per grade in grades 6-8 for a total of 6 team case studies. Students worked in teams of 2 − 3 team members during this Spring semester. Teams were selected through initial virtual interviews with the non-profit organization staff and teachers, who selected what they considered to be one lower, and one higher performing team per grade. We aimed to observe as broad a scope of phenomena as possible given our project resources and time teachers afforded us in the classroom. For the case study analysis we examined other sources including wiki log files, wiki history, teacher quarterly progress reports, game design evaluation results, and individual student blogs. Wiki activity was measured using both wiki history and wiki log files, which show the web trace of student activities of file uploads and page edits. We also observed published wiki team pages.

Data analysis. For the initial analysis, we adopted an inductive approach to the interview footage. All video data were uploaded into a qualitative data analysis web service (Dedoose.com). We were informed by the open, axial, and selective coding sequences of Corbin and Strauss (1990). Initial coding was conducted to discover major trends and themes resulting in a coding scheme. A

second round of coding was completed with the coding scheme. This coding involved "bracketing" video excerpts within a given interview session as events, and tagging the excerpt in Dedoose with appropriate codes. A third round of coding was conducted by pulling out just the instances of collaborative inquiry, and using a newer coding scheme with greater granularity that we developed through deeper review of this particular dimension. The codes are described in results.

Here we report upon collaborative inquiry instances only. The boundary for any given incident was the logical start and end of a given inquiry interaction by a student, using resources such as the wiki LMS, each other, and the teacher. Some instances were as brief as 10 seconds (e.g., a Google search); others were as lengthy as 2 minutes (e.g., a question and answer explanation interaction between a student and a teacher). In some cases, inquiry instances started, were interrupted, and re-started again a few seconds or minutes later. Such instances were coded separately, but memoed as "linked" to a prior inquiry incident.

2.1.4 Game Evaluation Outcomes

Game design project evaluation scores are based on a content analysis of each team game. Game quality is measured by content analysis of all teams' final games using a coding scheme for which inter-coder reliability was achieved (Reynolds & Chiu, 2012). Individual student blogs were also explored. For Dataset 1, we compared school-level page view findings with a ranking of average game evaluation scores at the schools. For Dataset 2, we compared team-level inquiry activity to a ranking of team-level game evaluation scores.

2.2 Results, Dataset 1.

As a "coordinating representation," the wiki LMS helps students orient and make sense of their game design activity. 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 *Profile page* frequency distribution for each of the 21 schools for standardized page views (i.e., average page views per student, across the entire school year) are as follows: low = 98; high = 1229; mean = 447.79; SD = 296.58. Results for *Project* pages are as follows: low = 0; high = 274; mean = 94.25; SD = 69.22. Results for *Team* pages are as follows low = 0; high = 190; mean = 56.35; SD = 61.53.

These 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. For relative comparison, we may interpret that for the school with the highest Team page findings (high of 190 page views across the school year), we might infer that the average student visits, saves and reloads the Team page about 5 times in a given class session across 38 days of the school year (or 10 times in a give day, across 19 days). Cross-time analyses at the class level were conducted but the class-level nature of the data restricts further depth of interpretation at individual or team levels. Nonetheless, standardization is meant to provide greater sense of relative scale of use. The high standard deviation results for these page types indicate that data points across schools are spread out over a large range, and that schools varied substantially in their extent of use of these pages.

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). The frequency distribution for each of the 21 schools for standardized page views (i.e., average page views per student across the entire school year) for *Intro* pages are as follows: low = 69; high =737; mean =279.12; SD =159.31. Results for *Wiki Tools* pages are as follows: low = 20; high =232; mean =79.90; SD =52.99. Results for *Unit 1* pages are as follows: low = 3; high =574; mean =75.77; SD =166.67. Results for *Unit 2* pages are as follows: low = 5; high =82; mean =31.34; SD =20.20. Results for *Unit 3* pages are low = 0; high =74; mean =19.57; SD =20.82. Results for *Unit 4* pages are low = 0; high =3; mean =.75; SD =.82. Results for *Actionscript* pages are low = 0; high =50; mean =8.22; SD =11.01.

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 (high of 3 pvs across the school year), this reads as quite minimal activity, indicating that for Unit 4, very little page view activity occurred across class sessions throughout the school year. While the latter units had low SDs because of the low Ns 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 are spread out over a large range, indicating that schools varied substantially in their use of the earlier units. So, only some schools saw higher use of the earlier units; not all.

Cross time activity. In the cross-time results (page view data broken out across 5 time increments), we do see spikes in engagement in the latter curriculum topics, at later points in the year, *for some schools*, which was expected. Profile page visits at most schools decline over time as would be expected as students engage further in visiting and editing the project and team pages (the locus for their use of the LMS as a coordinating representation to the extent that they post files, share work, etc.). For the curriculum pages, their uses of Intro decrease over time at most schools, which would be expected as students proceed through the subsequent units.

Relationships between Process and Outcomes. In addition to aggregate results, cross-time visualization of page views were organized into rank order by the school-level average for that school's team game quality evaluation scores, to more closely observe possible patterns of relationship between resource uses (as measured by page views) and game quality (i.e., student learning outcomes). Based on content analysis evaluation of team game quality as an outcome score, (described briefly in methods and fully in Reynolds & Chiu [2012]), the schools were split into a high performing group, a lower performing group, and a group of schools for which students created 0 games. The lower performing schools and those creating 0 games appear to visit the project and team pages substantially less frequently than the profiles. The higher performing schools appear to visit the team pages to a greater extent, and also more so as the program proceeds over time. Those schools with higher game evaluation scores appear to view Unit 2, Unit 3, Unit 4 and Actionscript curriculum more so than those with lower game evaluation scores. It appears that a trend towards escalating uses of the latter curriculum units in the latter semester phases is related to student game quality outcomes, as this also occurs more in the high performing schools.

If these results bear out quantitatively, then they indicate school-level differences such as teacher and student information literacy practices, teacher expertise, class management, etc. If game quality is correlated to more advanced resource uses, this also indicates that the resources can be helpful, if they are in fact used.

Overall, the page view findings suggest that while students at some schools are accessing and using at least units Intro – 3, the teachers may need help in structuring the course so that they reach the latter phases of the curriculum. Further, students may require greater support in information-seeking and resource uses in the context of this guided discovery-based program of game design and learning, in order to more fully realize the program goals. However, 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 results invite further questions of: How specifically are students using these resources? To what ends? In what ways are the resources deployed in their game design activity? What varying strategies of use emerge?

2.3 Results, Dataset 2.

The early phases of our inductive analysis of case study team video and our observations in the classroom identified the presence of two meta-processes that students engage in, that support the primary activity of game design and programming, and that in and of themselves are under-structured by the curriculum and teacher professional development: (a) student collaborative teamwork strategies, and (b) student information seeking and resource use. That is, some students have successes, and others have challenges because they are largely required to autonomously initiate and generate their own strategies for these two meta-processes (also supported by past research of Reynolds & Harel, 2010; Reynolds & Chiu, 2012). Thus, we focus on data reflecting incidents of collaboration and information seeking to better understand the inquiry processes undertaken, and the successes and challenges that emerge.

A categorical coding scheme was developed from our initial inductive analyses that allowed us to code the data for frequencies and conduct cross-tabs, for incidents reflecting the variables of "Task," "Collaborative Information Seeking Modality," and "Inquiry Outcome." Table 1 depicts the sub-codes we established for each variable, and their total N of incidents.

Frequencies, Task, CIS Modality, and Outcomes. Overall, student inquiry incidents occurred in support of the tasks of graphic design and drawing digital images most frequently, followed by the tasks of advanced and basic programming functions, game subject development, etc. per Table 1. The CIS modalities utilized in this social constructivist context were most frequently teammates helping each other with their own expertise, followed by solo student inquiry using the wider internet, students seeking and receiving help through inquiry of the teacher, etc. When combining the totals for frequency of wiki use incidents (whether solo, in team context, with teacher, or in classmate context), the N (69) is still less frequent overall than teammates helping each other with their own expertise (no informational resources). As for outcomes, most outcomes were coded as either successful or in progress. The total N of unsuccessful outcome results (across types of non-success) is 52, still less frequent overall than the successful or in-progress inquiry incidents, but not insubstantial across the 15 days of investigation.

Cross-tab findings, Task x CIS Modality. Cross-tab results for Task X Collaborative Information Seeking Modality indicate the task-specific breakdown of their collaborative information-seeking modalities. Overall, it appears that for graphic design tasks the students consulted each other and the internet more so, whereas for advanced programming, students made attempts to utilize informational wiki resources to a greater extent. These results indicate that the more difficult tasks are driving the digital

TABLE 1. Coding scheme and N of incidents for emergent collaborative information seeking (CIS) variables

Task		CIS Modality		Outcome	
Graphic design and drawing of digital images	93	Teammates helping each other with their own expertise	109	Successful solution found	151
Advanced programming functions	62	Solo inquiry using wider Internet	38	Task still in progress	103
Basic programming functions	52	Teacher helping student with their own expertise	36	No solution found, problem left in limbo	33
Game subject development	39	Teammates helping each other with wider internet	34	Not sure/ researcher unable to discern	14
Version control and file mgmt	15	Solo inquiry using wiki LMS	31	No solution found, task abandoned	8
How to search	12	Teammates helping each other using wiki	25	Problem solution found and tested but failed	6
Character animation	10	Help seeking from classmates with their own expertise	14	Problem solution found but rejected	5
Music	10	Teacher initiates help for student	13		
Not sure	10	Teacher helping student using wiki	11		
Sharing of formal feedback	8	Teacher helping student with wider internet	4		
Review of other games	5	Help seeking from classmates using wiki	2		
Basic computer functions	4	Classmates helping each other with wider internet	2		

information resource uses.

Cross-tab findings, CIS Modality x Outcome. We also considered the possible relationships between CIS modality, and Outcomes (i.e., successful versus failed searches). The results for CIS modality and inquiry outcomes indicate that when students asked fellow teammates and classmates for help and relied on their peers' expertise, the results had more failed attempts than other CIS modalities.

The school and teachers had instituted a sort of "inquiry chain of command" policy in Globaloria that required students to first check the wiki to answer a question, then ask a peer, and finally if

they could not find the answer, to ask a teacher. It may be that over-relying on teammates own expertise in this social constructivist context can in some cases restrict progress. However, the majority of peer help instances were coded as successful.

Another CIS modality with a higher proportion of failed attempts was for instances in which the teacher and the student worked together to try to find a solution on the wiki (which had a fairly low N, but occurred at a higher proportion for teacher/wiki use within that modality). It appears that some educators may not have full fluency with the learning management system in use, and the helpful resources therein.

Team level analysis and case study results. We also disaggregated the results to investigate team-level activity, to understand ways in which teams differ in their approaches. Frequency and cross-tab results at the team level of analysis confirm that teams do indeed vary substantially in the N of inquiry incidents supporting the various tasks, and various CIS modalities. Some teams engage much more so in programming, and their uses of the wiki LMS as a resource, whereas other teams engage much more so in graphic design. All teams engaged most frequently in seeking help from other team mates; their engagement in the other CIS modalities varied substantially however.

Team level relationships to outcomes. When we rank the six case study teams (2 sixth grade, 2 seventh grade and 2 eighth grade) in order of their game evaluation outcome results, we make the following observations:

- The higher ranked teams engage more frequently in inquiry supporting programming tasks (basic and advanced)

- While ALL teams engage most frequently in seeking help from other team mates utilizing their own expertise, the more frequently second-most utilized CIS modality for higher ranked teams is use of the wiki (either alone or as teammates).

- Teams that engaged most frequently in graphic design (over and above programming and other tasks) were the lowest 3 teams, and they did not use the wiki LMS as a resource in almost any instances.

We are still finalizing the analyses Dataset 2, and writing our team-level case studies in greater depth, with additional data sources including wiki artifacts that the case study teams created, and their own process notes from the blog and the wiki environment. Overall, the case study findings offer richer insights into the day to day inquiry practices of students engaged in inquiry and guided discovery-based learning.

2.4 Discussion

Dataset 1 offered course school-level insights as to what wiki resources were being accessed more frequently by what schools. The game evaluation outcome rankings lend insights into the possible apparent relationships between resource uses and outcomes. While students at many locations are not reaching latter phases of the curriculum, locations where they do appear to create more complex games. It appears from the Dataset 1 analysis that the less inquiry and wiki LMS resource the lower the quality of game, and the more wiki LMS resource uses, the greater the learning. The varying results for different schools invite questions as to what types of location-level differences in implementation context exist (i.e., why are some schools using more resources than others?).

Dataset 2 offers more granular insight into the nuances of student inquiry practices, at the individual and team level. It appears that uses of the wiki LMS by individuals and teams to support programming tasks in particular yield positive learning outcomes. But why are some students and teams more persistent in using these resources than others? Is this an individual or a team-level dynamic? Also, in this social constructivist context, students on the whole are much more likely to default to asking peers for help before seeking out information resources. Given that peer help had the highest N of unsuccessful outcomes, it may be that teachers should maintain greater vigilance about their policy prioritizing individuals' wiki LMS resource use as the first go-to source. However, positive outcomes were still more frequent than failed among the peer help interactions. Those designing social constructivist learning contexts should implement strategies for student team members to engage, when a solution is not found (besides leaving it in conversational limbo only to forget, or abandoning it altogether).

The results regarding apparent relationships between resource uses and learning outcomes (game quality) are co-present in both the school-level Google Analytics findings, and the team-level observational data. Neither set of results was tested quantitatively however, but support the hypothesis that resource use is connected to learning, and offers justification for testing the hypothesis in larger-N datasets in the future.

The data indicate that students may need greater scaffolding for information literacy and strategies for optimizing their collaboration practices, to improve the learning (e.g., searching online, greater orientation to the structure of the wiki LMS and its resources, team mate negotiation, task delegation, and perseverance through unanswered questions). These results have implications for information literacy instruction, especially as blended learning instructional models are more readily adopted by schools. And even still, 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. In what ways do such contexts challenge those who are less intrinsically oriented? Can inquiry or discovery-based learning contexts work *at all* for such students?

As the research agenda for this work moves forward, researchers may consider comparative analyses investigating what benefits are offered by inquiry or discovery based contexts, over other instructional models (e.g., those aiming to minimize cognitive load). Do collaborative inquiry and guided discovery contexts improve core knowledge domain outcomes over and above other instructional models? Do they offer students learning benefits that are peripheral to the core knowledge domain?

Our ongoing research investigates some of these questions, and the latest dataset includes screen capture data from 6 timeframes across the entire school year of 2013/2014 for 25 middle schoolers. We expect that these data, which will be conducted on minute-level intervals rather than incidents, for the entire dataset, will lead to insights about inquiry activity, relative to all the other activity that occurs. The study aims to more longitudinally chart students' collaborative inquiry and sense-making practices across the timeframe, and their growth and development of inquiry strategies as they proceed.

3. References

[1] Hmelo-Silver, C.E., Duncan, R.G., & Chinn, C.A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). Educational Psychologist, 42, 99-107.

[2] Kirschner, P.A., Sweller, J. & Clark, R.E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry based teaching. Educational Psychologist, 41, 75-86.

[3] Kuhlthau, C., Maniotes, L., & Caspari, A. (2012). *Guided inquiry design*: a framework for inquiry in your school. Westport, CT: Libraries Unlimited.

[4] Larusson, J. A. & Alterman, R. (2009). Wikis to support the "collaborative" part of collaborative learning. Computer-Supported Collaborative Learning, 4:371-402

[5] Paul, S.A., and Morris, M.R. (2011). Sensemaking in Collaborative Web Search. In *Human Computer Interaction* Special Issue on *Sensemaking* (Special Issue Eds. Daniel Russell and Peter Pirolli). 26(1), 38-71.

[6] Reynolds, R., & Chiu, M. (2012). Contribution of motivational orientations to student outcomes in a discovery-based program of game design learning. Proceedings of the *International Conference of the Learning Sciences* (ICLS), July 2012, Sydney, Australia.

[7] Reynolds, R., Harel Caperton, I. (2009). The emergence of 6 contemporary learning abilities in high school students as they develop and design interactive games. Paper presented at the American Educational Research Association annual conference, April 2009.

[8] Reynolds, R., & Harel Caperton, I. (2011). Contrasts in student engagement, meaning-making, dislikes, and challenges in a discovery-based program of game design learning. *Journal of Educational Technology Research and Development*, 59(2), pp. 267-289.

[9] Reynolds, R.; Baik, E.B. & Li, X. (2013). Collaborative information seeking in the wild: Middle-schoolers' self-initiated teamwork strategies to support game design. Paper presented at the annual convention of the *American Society for Information Science and Technology* (ASIST), 2013.

[10] Reynolds, R., Hmelo-Silver, C. (2013). Areas of theoretical convergence in the Globaloria game design initiative: Constructionism, knowledge building and guided discovery based learning. Paper presented at the *American Education Research Association* (AERA), San Francisco, CA, April, 2013.

[11] Reynolds, R. (2014, submitted). Challenges in defining, designing, and measuring "Digital Literacy" development in learners: A proposed framework.

[12] Salomon, G., Perkins, D. & Globerson, T. (1991). Partners in Cognition: Extending Human Intelligence with Intelligent Technologies. Educational Researcher, April 1991, pgs 2-9