Collaborative Information Seeking in the Wild: Middle-Schoolers' Self-Initiated Teamwork Strategies to Support Game Design

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ABSTRACT
This study investigates how students learn to collaborate in a guided discovery-based program of game design learning, and how e-learning systems and environmental supports afford collaboration. We address how students self-initiate and strategize collaborative practices to achieve a project-based learning goal, and how they interact with peers, teachers, and technology to develop a shared understanding of the primary game design task. We also consider student engagement in the meta-processes that support this task's completion, such as delegation, teamwork, and resource use. The methods applied include two main steps - categorical analysis of 18 teams' interview transcripts and in depth case study analysis of four teams' interview responses and process artifacts, with a focus on the themes that are identified from the first step. We propose an initial framework outlining general dimensions of collaborative information behavior for knowledge building contexts. And we conclude with questions for future research.

Keywords
Collaboration, blended learning, game design, discovery-based learning, case study.

INTRODUCTION
Understanding how students learn to collaborate and how learning environments can afford effective collaboration are critical for cultivating knowledge sharing, networking, and innovation in classrooms (Barron, Martin, Mercier, Pea, Steinbock & Walter, 2009). Our research aims to describe how an e-learning system involving game design affords and structures middle schoolers' collaboration. We address how students self-initiate and strategize collaborative practices to achieve a project-based learning goal, and how they interact with peers, teachers, and technology to develop a shared understanding of the primary game design task. We also consider student engagement in the meta-processes that support this task's completion, such as delegation, teamwork, and resource use. This study has implications for understanding students' self-initiated collaborative and role-taking strategies in educational contexts where they receive little scaffolding for teamwork practices. The study can inform designers' improvement of e-learning information systems, curriculum, and socio-technical system design for collaboration in other contexts more broadly.

LITERATURE REVIEW
The program in which this study is conducted aims to teach students and educators how to use a range of technologies for productive, constructive project-based work, and to raise student awareness and interest in STEM careers, through participation in a year-long game design intervention. The design of the program embodies many of the principles of Constructionism (Harel & Papert, 1991) and distributed cognition (Salomon, 1993).

Discovery-based learning, Constructionism and Distributed Cognition
Consistent with sociocultural theory perspectives, in Constructionism, learners benefit from social interactions and sharing throughout the process of creating a computational artifact often involving programming. The early work on Constructionism found that engaging students in game design in a collaborative classroom setting for the purpose of teaching younger students about school subject material (mathematics) fostered deep epistemological thinking, providing students with the opportunity for "learning how to learn" (Harel, 1991; Papert, 1993). There is converging evidence of these positive results in other studies using a number of different technology innovations in place of Logo, including Microworlds Logo, Scratch, the MaMaMedia web environment, as well as off-the-shelf technologies (e.g., Kafai, 1995; Bruckman & Resnick, 1995; Kafai & Resnick, 1996; Urrea, 2001, 2002; Cavallo, 2004; Kafai & Ching, 2004; Kafai, 2006; Peppler, Kafai & Chiu, 2007; Klopfer, 2008; Reynolds, 2008). These follow-up results have

supported Harel's earlier work indicating that student engagement in such interventions builds meta-cognitive skills, establishes meaning-making, and leads to positive affective gains. Designing game artifacts has more recently been found to provide opportunities for learners to reify their thinking and make it visible in a concrete and tangible form-- and thus open to reflection and revision (Salen et al., in press). However, students' emergent collaborative practices in such contexts has been under-investigated, especially at the middle school level.

Related Approaches of Situated Learning. Several approaches to situated learning described in the literature have qualities related to Constructionism. Many have demonstrated positive outcomes. Project-based learning interventions are those in which learners construct artifacts of varied types, in an open-ended, inquiry context. Such interventions have been shown to enhance engagement and motivation to learn, increase meaning-making and connection with the material at hand, foster the learning of soft skills such as collaboration and project management, as well as improve test scores in core curricular areas related to the domain of project creation (e.g., Geier et al, 2008; Blumenfeld, Soloway, Marx, Krajcik, Guzdial & Palincsar, 1991; Krajcik. & Blumenfeld, 2006; Blumenfeld, Kempler, Krajcik & Blumenfeld, 2006).

In *problem*-based learning (PBL) (e.g., Hmelo-Silver, 2004, 2006; Hmelo-Silver & Barrows, 2006; Hmelo-Silver, Derry, Bitterman, Hatrak, 2009), students learn through facilitated problem solving of complex problems that do not have a single correct answer. Students work in collaborative groups to identify what they need to learn in order to solve a problem. They engage in self-directed learning (SDL), apply their new knowledge to the problem, and reflect on what they learned and the effectiveness of the strategies they employed (Hmelo-Silver, 2004). Similarly, Kuhlthau's (2010) "guided inquiry" model views students as active agents who gain the ability to use digital and informational tools and resources for core curricular studies through a constructivist "information search process", in which students can learn together in a community context. In all these situated approaches, scaffolding and facilitation are distributed among the tools, artifacts and **social** resources of the learning environment. The *guided discovery-based approach* is loosely defined as instruction in which students "must discover or construct essential information for themselves" rather than being "provided information that fully explains the concepts and procedures" (Kirschner, Sweller, & Cark, 2006, p.75). Constructing is a social process.

In a traditional classroom instructors aim to impart information and skill sets to students for knowledge acquisition in a logical sequence in which everyone shares the same learning goals (Stahl, 2006). Constructionists argue that learning environments should be tailored to individual student learning styles and phases, and that students must have opportunities to discover and guide their own learning through interaction with peers, to reach insights in their own ways (Papert, 1993; Stahl, 2006). Students can interpret problems using personally developed conceptual frameworks with their experience and prior knowledge, and actively construct their own knowledge through creative expression and action in the environment, rather than just adopting existing learning materials and information and working at the individual level (Stahl, 2006).

The program we are investigating herein entails students' team-based design and programming of a computational game artifact, in a setting embodying guided discovery. Students proceed individually through a sequence of prescribed activities for the first one to two months, and then transition to team-based game design driven by collaboratively derived plans and ideas, using a variety of resources. The design of this program leverages distributed cognition in that students can openly receive support and assistance from a variety of resources surrounding them including each other, and create shared artifacts representing their ideas.

A wiki e-learning platform serves as a representational support – as "an intelligent technology that can undertake a significant part of the cognitive process that otherwise would have to be managed by the person" (Salomon, Perkins & Globerson, 1991). Larussen and Alterman (2009) discuss wikis as a coordinating representation in research on college students' co-located project-based teamwork, stating such environments can be "shared among participants and designed to make it easier for actors to work in parallel and multitask and make 'common sense' of the situation and how to proceed with the action" (p. 375). They investigate how preformatted wikis might be useful to support project-based work for team members in a co-located context, stating that "scaffolding a wiki with project-related material can create a representational structure that guides and organizes the students' interactions, concentrated on the key aspects of their collaboration" (p. 379). The authors suggest that in such an application, "the scaffolding functions as a coordinating representation, which helps the students coordinate and share a common view of their cooperative activity" (p. 379).

The program under investigation employs a similar approach. A pre-formatted learning management system built upon wiki architecture contains the course syllabus, tutorials, areas for student and teacher messaging and dialogue, areas for uploading and file-sharing towards project management, and presentation and documentation of work.

Another important aspect of distributed cognition is collaboration itself. One way to support guided discovery in teams is to assign student roles (Herrenkohl & Guerra, 1998; Martin & Barron, 2009). In contrast, this program employs self-organized collaboration among team members, which resembles that adopted by Larusson and Alterman's (2009) case study. In such collaborative contexts, individuals self-identify their roles based on personal preference. This is similar to research that has examined emergent roles, sometimes showing that students develop individual areas of expertise and functional specializations (Miller et al., 2013; Hmelo-Silver et al., 2009). Such self-organized collaborative approaches among middle school-aged children in the classroom are rare due to the traditional classroom norms that emphasize homogeneous knowledge development.

In the field of information science, the roles that an individual actor takes in social life initiates personal information needs. Information needs drive information seeking behavior (Wilson, 2006). Wilson states, "at the work-role level it will be clear that the performance of particular tasks, and the processes of planning and decision-making, will be the principal generators of cognitive needs; while the nature of the organization, coupled with the individual's personality structure, will create affective needs such as the need for achievement, for self-expression and self-actualization" (p. 665). In this program, students' collaborative engagement is centered on their task-driven need to complete a functioning game (and all the interim steps involved in this process). We investigate students' collaborative approaches in this context.

Collaborative **Information Behavior Research**

Collaborative information behavior research is shedding light on information practices as socially constructed processes towards achievement of a shared goal. Tuominen, Talja and Savolainen (2005) state that information behavior "assumes that the processes of information seeking and use are constituted socially and dialogically, rather than based on the ideas and motives of individual actors. Information practice is mainly inspired by the idea of social constructionism (Savolainen, 2007). All human practices are social, and they originate from interactions between the members of community" (p.328). The broad definition of collaborative information behavior (CIB) is "an activity where two or more actors communicate to identify information for accomplishing a task or solving a problem" (Talja & Hansen, 2006, p.114). CIB is emerging as a new direction and central to research on human information behavior (Talja & Hansen, 2006).

In this program, students actively engage in CIB practices, in that student teams must identify, interpret, and plan tasks to create a playable game as a shared goal, and utilize resources and information provided via the wiki LMS and within the class environment (such as each other and their teachers).

The overall research question guiding this study was, "What collaborative information behaviors do middle school students evidence when given the chance to self-organize their game design task-driven teamwork?" The work aims to inform our ongoing analyses and refinement of hypothetical models, in explaining student engagement and learning processes within this social learning system.

METHODS

Intervention. In the program under investigation, students learn to develop an educational interactive computer game as part of an in-school class in which the primary goal from the students' perspective is the successful completion of a functioning web game using Adobe Flash software. The program provides wiki-based curriculum and instructional supports including teacher professional development trainings, on-location and virtual instruction from industry experts, online video and text tutorials, and a virtual help desk available during school hours. The non-profit that runs the program provided twice-annual in-person teacher training workshops, the e-learning platform, ongoing webinars with students and teachers and a virtual help desk. In-school classes followed a blended learning curriculum daily, for up to 90 minutes per session, across either a semester or a full year. Educators were minimally trained on supporting collaboration and teamwork processes. Students chose their own teams and largely self-organized, delegating tasks and roles. The wiki featured an informational text page text outlining types of team roles.

Participants

Student case teams for interviews were selected from three schools in which students in grades 6-8 are participating in this program in WV and TX. Students worked in teams of 2 – 3 towards completing a final, functioning web game as a result of their participation (either over 1 semester or 1 year). Teams were selected through initial virtual interviews with the non-profit organization staff and teachers, who selected what they considered to be one low, two mid, and one high performing teams. We interviewed 18 teams in person during initial site visits to WV and TX. Then we interviewed students virtually over Adobe Connect using the screen sharing feature so students could demo their work while discussing. After analyzing the data as described below, we chose four teams of focus for in depth case study. Two teams were comprised of all boys, one team was comprised of all girls, and one team consisted of two girls and one boy. We chose teams representing teacher's initial impressions of low, mid and top performers. Our unit of analysis was the team.

Data Sources

Data sources for the interviews included video recorded face-to-face and virtual interviews with student teams. 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.

Teacher quarterly progress reports offer teachers reflections on class progress and specific students' performance at both a team level and an individual level.

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, 2013). Individual student blogs were also explored.

Data Analysis

Data analysis occurred in two separate steps.

Step 1: Categorical analysis

Our interview questions were semi-structured, centering on students' choice of game topics, collaboration, information uses, process, and challenges in programming. We had a set of questions that framed the interviews. We allowed student responses to guide follow-up questions. For the analysis, we adopted an inductive approach to the interview footage. Prior to the first phase of analysis, 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), although these sequences were not followed strictly. Initial coding was conducted to discover major trends and themes and a second, more selective round of coding was completed to reveal more granular themes.

We first watched 3 of the 18 initial Time-1 (T1) interviews. Categories of focus in the first round of analysis were collaboration and resource use. Under these two broad themes, we created an initial set of categories at 3 nested levels based on student primary tasks (game design/planning, programming, game topic development), with about 15 sub-categories beneath each. We commenced the selective coding of all 18 interviews conducted at T1. This coding involved "bracketing" video excerpts within a given interview session as events, tagging the excerpt with appropriate codes.

In the second round, we selected just the excerpts coded as collaboration, transcribed all events, added text-based transcripts to Dedoose, and engaged in another coding round at the text-level, using the sub-codes generated previously and adding others revealed through analysis of the transcribed text. Finally, we chose the three main sub-codes of focus that emerged for collaboration to report in this study. The sub-codes are discussed and explained in the results, and include sample data of student responses.

Step 2: Case study analysis

For the case study, we chose four teams from the interview dataset, across teacher-evaluated performance levels. We extracted data from eclectic data sources, and chronologically organized data by team member and by data source in one Excel file. Then, we observed patterns, identified areas of convergence and divergence, and compared to interview categorical findings.

We then integrated categorical and case file findings across three main themes, and also identified new findings emerging from cases. We identified areas of convergence and divergence, in comparison to the interview study's categorical findings. Initially, we investigated all data sources for each team, and aggregated the evidence relevant to collaboration for each team (e.g., blog posts, wiki team page edits, patterns of edit and upload activity across team members over time, and specific interview expression provided by the team members). We saved this evidence in one Excel file with a team in each tab, and chronologically organized the data by students, and by data sources to compare and contrast the activities of students and teams over time. Then, from our organized data file we extracted case examples in terms of the three themes identified from our interview study.

RESULTS

As we analyzed the interview data, two main themes related to collaboration offered evidence of distributed cognition: (a) variations in students' strategies for self-organization, and the natural formations of role-taking and division of labor that students initiated, (b) ways in which students report receiving help from peers and learning a new process for seeking assistance. Further, students' struggles in managing file-sharing and version control in their game artifacts, among team members was a category that indicates some potential issues with the extent of structure that the e-learning program and system offers to students.

Role-taking and division of labor

Categorical analysis findings.

One thing that stood out in the interview data was the way in which students discussed understanding the need to self-organize into team roles, and divide up tasks in line with the role-taking. Teamwork was challenging for many teams; students reported difficulties self-organizing, negotiating tasks and cooperating. For instance, one student states "*it can be hard for teams to really figure out how to work together. It's not easy and you don't usually do that in class so its new…a new thing for you*." In another example, a student mentioned a lot of arguments in her team, and her partner states "Y*eah, we were trying to work with each other at first, and try to do all the levels on our own and try to do it and I didn't get what level was supposed to be, so what I did was put on my flash drive and I put it on my wiki, and I started working on my own, so it was split in two levels. So she had that one and I have mine. Yeah, so we can do whatever we want on our own level, so we just split apart like that, split the work into halve*s."

Teams self-reported variation in strategies for self-organization, role-taking and division of labor. At the start of the program, the curriculum introduced students to information about game design roles, such as graphic designer, programmer, project manager, and researcher. Students were encouraged to identify with and appropriate the role and tasks they felt they would most excel at. Teachers explained that students may take on multiple roles in a given team to complete the game, and students can experiment with varying roles throughout. For instance, one student states, "*I'm a little bit better drawer than he is and a better searcher than he is and he's better with the code and getting things to work than I am. So I usually do the drawing and save to link, and he usually does the coding and makes things to work.*" Another student states, "*we go by who knows how to do it, and anybody doesn't know how to do it then we all try to work on it together.*" Another states, "*we are honest with each other, so say somebody performs something better than somebody, we will tell them, say, William did buttons better than Justin. But that's not true though. We got to be honest or we were not going to get a full game. I'm good at flash and he's good at buttons…at first we were kind of raw but we all worked together.*"

Data indicate that in classrooms, individuals take on the role suited to them and that they prefer. Awareness among students of a variation in expertise emerges, and certain students become recognized for their expertise in specialized areas. Then, they are sought out by other peers in class for specific help, similar to the research of Hmelo-Silver, Katic, Nagarajan, and Chernobilsky (2007) and Miller et al (in press). Some students emerge as new leaders.

Case study analysis findings.

Case study data indicate that students assign their roles at the beginning of game design process, and mainly keep the initial roles except a couple of incidents. In the team Sparklies, Cameron, Emily, and Jasmine describe their roles as a *gopher*, *supervisor*, and *brain* respectively, at the beginning of their programming phase according to their timeline table on the wiki team page. Their teacher reported that Cameron knows well where to get helps for their problems, backing up the students' identification as "gopher." Emily's blog indicates Cameron completed project pages and learning logs, Emily completed graphics and layouts, and Jasmine did *a little bit of everything*. We found that Jasmine mainly engaged in wiki edits, programming, and uploading files from our wiki history and trace analysis. Similar to the team Controllers, all members in the team Sparklies are also involved in various tasks to achieve their shared goal, a playable game artifact. Like the two other teams, Halo also decided their roles based on perceived expertise and interests. Both students in this team responded in the survey as identifying as game idea thinker; game idea researcher; and flash tutorial researcher, but Hailey only indicated as a graphic designer while Anna responded roles as wiki page uploader, wiki file uploader, programmer, and project manager/ planner. This result is in line with their expression of interests in their paper prototype presentation video as well as consistent with the first phase of our interview. Anna states "*I have to do more actions and she did the design*."

Ongoing research will aim to better understand how allowing students to self-organize might lead to stronger preferential identification with roles and tasks, and might contribute to the emergence of expertise recognition, and subsequently, peer help which data we describe next. We will also consider students' reflective meta-cognition about the need to communicate on team member role-taking within the team (and whether and how this might influence team member affect, e.g., hurt feelings or de-motivation). Further, the instructional design decision to allow students to specialize means that not all students learn the same material – very different from regular school culture. While students shift and vary somewhat, and learn a common base of game design expertise before moving into teamwork, this eclectic approach needs further investigation and consideration for its implications in school culture.

Peer help

This program is designed as a synchronous and collocated interactive class, and the workshop studio-based setting allows students to be aware of each other's work, to engage in substantive in-class dialogue to remain coordinated, while alternating between (a) working independently on a delegated task on their own respective computer, and (b) working on a shared task on one of the computers, together. This context makes them to easier ask peers for help.

Categorical analysis findings.

A culture of informal peer teaching appeared to take hold in the game design classrooms. Many students reported that their teachers had established a prescribed set of problem-solving steps for students to follow when experiencing a hurdle: first they must visit the wiki to find answers, then ask a team member or peer in the class, and finally, the last resort is to ask the teacher for help. Educators in this program are encouraged to adopt this approach in professional development in professional development. In the interview, a student states that he decide to ask the teacher as question after looking up the wiki first. His partner states "*We would go on the wiki and try to see in it, if we don't get it, we would ask each other, then if nobody gets it, you ask a friend*." Some seem to enjoy and understand this approach well. One states, "*I just ask someone, 'could you please check on my work,' and then they would go 'yea can you check mine,' and we check it, that's how we know what we are doing wrong*."

In this context, certain students became recognized for their acumen in specialized areas such as programming, and were sought out by other peers in class for specific help. Students report gaining actual expertise as a result of the interactions with their peers. One student states "*You get help from other classmates if the team can't figure it out. We have different other classmates that can teach us. First* *we didn't know how to make a button, and one our classmates taught us how. And now we know how to make the buttons and put sounds into it.*" Another student notes that he is most proud of how much he achieved by using codes and programming, and states, "*Because a lot of people ask us how we make the button codes, because you have to change them around. If you want to click back you have to put in more brackets. People asked us to help other people too*." Teachers informed us that some of these game design leaders were under-performers in traditional school, and upon participating in this class, had made clear gains in knowledge, social standing, and self-esteem. Student experts we interviewed appeared to enjoy this new role, and the value proffered by the community upon their expertise. Other students also reported gaining expertise and learning through their interactions with the expert peers.

This finding on self-reported expertise development through peer sharing is notable, given that often students are restricted from sharing of work with each other in the regular school classroom. One student points out this difference, noting that *"…cause usually other teachers…when you ask a student, they think you are cheating 'cause students do the same thing. But in this class you can't really cheat, because we all work on different things... the other two partners work on astronomy and you work on math ….so how are you gonna cheat?*" If everyone is learning something different, and distributed cognition is valued, then the concept of cheating changes. What comprises cheating in a Constructionist game design is a question worth future study. For instance, we do see evidence suggesting that student teams become competitive around intellectual property at times.

Case study analysis findings.

One of the key aspects in collaborative learning is social interaction (Haythornthwaite, 2006). Through communication and discussion with others, students can be timely and immediately supported and helped by their team members at the point of their needs (Haythornthwaite et al., 2000; McGrath, 1984). Also, this interaction and communication (social support) help students have a sense of belonging to a community or team. S*uch activities also increase commitment to group goals, and trust among group members* (McGrath, 1984). We mainly looked up blog postings and interviews to investigate student expressions of peer help in case studies.

In intergroup interaction, the Controllers helped other classmates on programming after they successfully solved their problem, they gave help for other teams. They became recognized for their proficient programming ability in specialized skills such as hit test coding and were sought out by other peers in class for specific help. In our second interview, Zackery states that *"when we figured out how to do the hit test with the flags, we were able to help some other people with hit tests on it, and it was for this whole class using that hit test almost two groups and one...... With the help of the help desk's help, we were able to help them fix the game.*" When they couldn't figure out solutions for other classmates, Donovan and Zackery even sought out for help from the wiki help desk experts from the non-profit.

The students in Halo students expressed some struggles and frustration with some programming, and help received from others. Hailey wrote "*I have watched the videos probably thousands of times! I have read the course schedule probably THOUSANDS OF TIMES!!! Yet, I cannot do it. Well, I'm trying. We just had one of our classmates help us and I hope that this works. I better get to work now*!" When we asked them how they resolved their frustration in game design, Anna states "*Well, sometimes you don't understand something, you would go to the people who have done this before, looking if they have any tips or any other stuff."* Also, they said that they actively sought out for help from various people in their class. The findings for peer help offer support for distributed cognition but at the same time indicate frustrations that sometimes arise in such an agentive setting.

Version control

One challenge students faced was keeping track of game file versions. Because of variation in self-organizing teamwork processes, students required varying strategies for merging distributed work and project files. Merging is particularly challenging when using Flash because all .FLA files are stored in binary format. There is no meaningful way to compare two different documents to note changes between an old version and a new one, besides viewing all the layers. No plaintext versions of coding or graphic view of changes exist in the current workflow. Version control issues appeared to have challenged some groups' productivity. Adobe Flash source files do not lend themselves easily to version control.

Teams whose students choose to delegate tasks in Flash to different individuals requires that each one maintains own most updated files, and that team members coordinate the merging of the different versions of their individual files at various points to create a shared "master." Students are given flash drives to help, but teachers and students report that these occasionally become lost. The wiki is meant to help them project manage this process, however most teams soon realize this can be somewhat unwieldy. Although daily updating and use of the wiki for project management is the aim, there are no set rules for when students upload, but many teachers include file uploading as one of criteria for student assessment. However, this approach is time-consuming and overall it appears that version control is resulting in lost time and data.

Categorical analysis findings.

Teams reported using flash drives to transfer shared files, which occasionally became lost. Some teams emailed each other files. Attempting to control for the complexity of managing many different tasks, a few teams reported dedicating use of a particular computer for a particular function. For instance, one students states "*Well, what we usually do is use that one computer just for flash and one for wiki and to code video things and we usually switch computers for flash. We usually just follow the team page and when we start to make ourselves confused, we use that.*" Such a strategy may reveal that some students struggled to conceptualize parallel multi-tasking capabilities such as multiple file tabs in Flash project files, SWF files, folders, and file management in general. Similarly, some students reported sharing their login credentials for the wiki with each other, enabling a given individual to log into another's account and upload his/her files into the other's file gallery as one mode of transfer (when they could simply login and upload as themselves to make files accessible to all classmates on the wiki). For example, some students discuss how they merge graphics and programming code between two students by importing graphics into the Flash library in their master file. Student 1 states "*We just copied off the idea. I don't like the pencil tool cause it always draws something so jaggy*." Then his partner states "*Like in the library, where when you do like an instance name, it saves into the library area and there it is….This is what we did, we drag it out, making a second parrot.*" They have game demo file open and the destination file open. Then they dragged the parrot into their master file.

A solution we heard more than once was students sharing their credentials for the wiki with each other, using a single username and password for their work, and logging into different machines with the same user ID. This method guarantees that all work will be saved in one user's file gallery, but as was seen with the use of flash drives, can result in file over-writes. Further, as we move into the analysis of wiki log files, the userID is the primary unique identifier, but activity on that userID may not represent the work of a single student. In other words, given this strategy of self-organizing middle schoolers, the wiki log files as a data source for investigating teamwork, and for evaluating / assessing individual student efforts needs to be further investigated for validity.

This is not an issue that is easily addressed because the format of an Adobe Flash source file does not lend itself easily to version control. Learning to collaborate with others often means learning conventions that must be adhered to in order for everyone in a group to work together. Perhaps an agreed upon naming convention for files or a five minute session for consolidation and resolving conflicts at the end of coding or drawing could be used here.

Case study analysis findings.

Throughout the year, the Sparklies tried hard to learn Flash programming, but their final game is not playable. When we examined their game files, they had built layers and various elements, but they were not functioning at the end. According to wiki log, Jasmine tried to make their game work even after the final submission, but she was only successful with button functions and ended up with two pages of final games (i.e., one title page and one introduction page).

During the first interview, the interviewer asked students about merging, and Emily states, "*All the things we have in it are on the flash drive here*." Jasmine's blog posting indicates their ultimate struggles. She states "*Combining different codes......Things like Drag & Drop, Hit Test, & animated movie clips can be put into one frame to make the scene more challenging for the player. Yes, it's frustrating trying to add it all in, but if you do manage to get it all worked in, it would def. be worth it!...Originally, Team Sparklies had planned on using click buttons and keyboard control on our game......*"; and "...... *Throughout the year we've had struggles......*"). It appears that merging and putting together final pieces was a challenge.

To deal with their game versioning, Halo used file naming conventions such as updated version with the higher number in the file name (e.g., game demo 4, game demo 5, and so on). They named their game files in the order of more updated version, and posted them on the wiki. These files built upon each other and were improved based on the previous file. For instance, Demo4 had navigation buttons added on all the scenes and the buttons worked; and Demo5 added sound on buttons. On top of the previous elements, the Demo8 contained a layer that enabled the Alien to move; keyboard control; and "drag and drop" on their pictures on the team introduction scene. When they build more codes on top of current file, they changed file name to indicate version is upgraded. They think that their version control went well (e.g., interviewer: *so the flash file sharing has been going OK* and Student 2: *(nodding)*). This team's final game successfully worked in an integrated fashion.

Other Findings from Case Studies

In addition to three categorical findings from our data sources, we observed some other findings.

Several students expressed their enthusiasm and excitement about collaboration. For instance, Nathaniel mentioned "*the funnest thing for me is working with my team and making all these…*" Further, while teams with female students were active in posting in their blogs and wiki team page edits and updates, the team Controllers and Scream composed with all male students showed less activity in posting. A teacher reported that two students in the Controllers loved the class but did not keep up their blogs and wiki updates. We had more qualitative records from the teams with girls. To investigate how gender is related to team performance and productivity may inform understanding of team dynamics.

Further, extent of student effort on various tasks varied within teams and may have been driven by role. Some students reported idle time, waiting for teammates to progress. Some teams also worked outside of class to complete their games. Zackery of Controllers states in the second interview, "*In the last couple of weeks, me and Don have worked even out of class, and we just pretty much pick up what we have left to do, and go as fast as we can.*" A teacher also reported that Anna and Hailey in Halo came to school early in the mornings to work. This factor might result in the higher scores both teams achieved in their final game evaluation.

During the collaborative process in game design and learning, some teams experienced conflicts during decision making. Scream team's William states, "*At one point we were farther than everybody in the class then we kinda…*" Nathaniel follows, *"it started slipping*." Justin explains, "*We started to argue a lo*t." Then, William states, "*Nathaniel started arguing with Justin a lot and I would sit back like 'when is this going to end'*." The teacher observed that Nathaniel had a hard time working in a team although he is very confident about his computer abilities. She reported that at one point Nathaniel erased all works that his team had built due to discontent about the teamwork. This fact indicates that his disagreement and unsuccessful negotiation in his team caused their broken teamwork during their game design project. The failure of the negotiation about game ideas between Nathaniel and Justin might be a reason why their progress became slower.

Originally, the game idea was suggested by Nathaniel, and then both Justin and William agreed on his ideas. As the teacher pointed out that Nathaniel is full of ideas, but his concept was too broad for this project. In the interview, Nathaniel self-recognized his issue and mentioned it. On top of the tension between Nathaniel and Justin, it seems that William did not play any role to resolve their issues, and just stayed back rather than getting involved. It did seem the boys eventually found a way to cooperate to create a finished game product. The case highlights the need for more observational data collection.

DISCUSSION

In this program, students self-organize in their collaborative teamwork to meet their goal of developing a fully functioning web game. Individuals take on the role suited to them and that they prefer. Awareness among students of a variation in expertise emerges, and certain students become recognized for their expertise in specialized areas, and are then sought out by other peers in class for specific help, an overall phenomenon which is reported as well in Hmelo-Silver, Katic, Nagarajan, and Chernobilsky (2007) and Miller et al (in press). These results appear to relate to Barron's (2003) observation that "it may be that students develop metaknowledge about joint activity that they use in interaction with others. There is evidence that following an intensive collaborative design experience, some students develop insights about collaborative work processes (Barron et al., 2002). How general are these metacommunicative reflections? Do these kinds of insights transfer to other collaborative contexts?" (p.353). These questions surface as well from the findings reported herein.

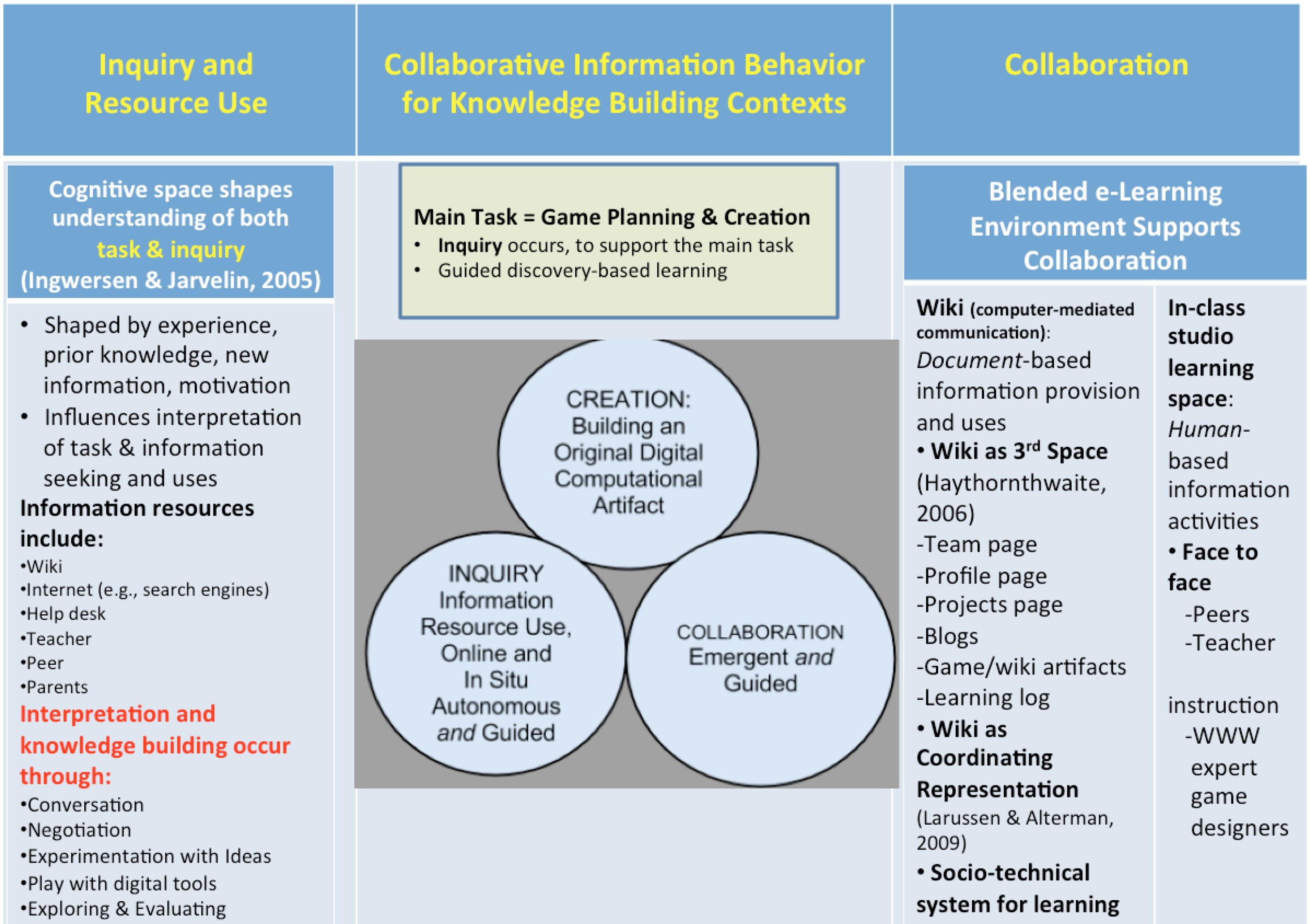
In a project-based work context somewhat similar to the one we are investigating but with college students, Larussen and Alterman (2007) investigate in what ways students' collaborative activity is tightly versus loosely coupled in a close problem space involving wiki-based scaffolds (which it did in their context), and whether the wiki fulfilled its aims as a coordinating representation (which it also did in their context). Our case study could not offer explicit insights on coupling but it does appear the younger students need more support. Other research in computer supported collaborative learning (CSCL) investigates how prescribed role-taking strategies can be effective, and Kuhlthau et al's guided inquiry approach offers collaboration strategies as well (Kuhlthau, Maniotes & Caspari, 2012). We aim to test some of these approaches in the future using observational data collection currently underway. It also appears that the wiki did not always successfully coordinate student file sharing; students pursued workarounds. Student task-driven resource uses will be investigated, considering absence of information literacy scaffolds, and potential for their development, drawing from Kuhlthau's guided inquiry approaches.

Hypothesized Model of Collaboration and Information Behavior in Globarloria

People often engage in collaborative work in a group, and solve a problem together through interaction with their group members. The nature of work is inherently social and interactive, and the design of information systems and tools should be able to support multiple users working together rather than focus on individual working independently (Talja & Hansen, 2006).

We propose a model of task-driven collaborative information seeking **for knowledge building in project-based learning contexts in particular,** that integrates work occurring in the learning sciences (e.g., Constructionist game design and distributed cognition), and, the information sciences (e.g., CIB). The current version of our hypothesized model presents the dimension of collaboration on the left side. In this study we have begun to draw out a greater understanding of the emergent collaborative processes students undertake, when given little scaffolding for teamwork practices (and some of the challenges they encounter). We see the expression of collaboration in this program in two dimensions (Talja & Hansen, 2006; Hansen & Jarvelin, 2004): (1) collaborative activities in the wiki environment (a medium of computer-mediated communication) where *document-based* information activities happen; and (2) collaborative activities in the in-class environment where *human-based* information activities occur. *Document-based* information activities in collaboration are involved *in creating or using documents (electronic or paper-based), such as "working notes" that* may contain information about search strategy, query terms and classification codes etc. (Hansen & Jarvelin, 2004, p.1110). Human–related collaborative activities directly use knowledge possessed by other humans in the patent handling process (e.g., asking colleagues internally and externally for advice and expert judgments) (Hansen & Jarvelin, 2004, p.1111). The system appears to support collaboration in both dimensions but may be under-structuring it.

Figure 1. Collaborative Information Behavior for Knowledge Building Contexts



On the right side, we present the cognitive aspects of actors and the resources present in this program. To support the main game design task, inquiry occurs, driven by information needs that arise in the moment. The information seeker's cognitive space consists of his/her experience, prior knowledge, new information, and motivation (Ingwersen & Jarvelin, 2005, p.276). This cognitive space influences or shapes the interpretation of task and information seeking and uses (i.e., information practice), and vice versa. The main locus of interpretation consists of students' interactions with other actors and creative processes -- through conversation; negotiation; experimentation with ideas; play with digital tools; exploration; and evaluation and use of more authoritative information sources online and from their teacher.

CONCLUSION

Although this study focused on collaboration, we find that resource use phenomena are difficult to separate from collaboration, hence our inclusion of the inquiry dimension. For instance, we expect information practices may vary based on student role-taking, because different roles have different tasks. Future work will address the interconnections between inquiry and collaboration in this knowledge building context. We are continuing our investigation drawing upon observational video footage recently collected in situ. Students' digital artifact creation generates an additional resource that is not yet represented in the CIB. Student games themselves are key information sources for shared knowledge building and elaboration of ideas. User-generated content is a variable that must be added to the socio-constructivist CIB conceptualization. We anticipate describing our model as a "Collaborative Information Seeking (CIS) Model for Knowledge Building Contexts (KBC)" – CIS for KBC. This model will both (a) explain phenomena we observe in the implementation of this theoretically driven guided discovery-based program, (b) serve as a comparative framework which dynamics can be explored as potentially explanatory of research findings in other discovery- and/or project-based learning contexts that entail variations in design, and (c) serve as a prescriptive guide for learning intervention design.

Our current study describes how a guided discovery-based program of game design learning affords, and appears to under-structure, middle schoolers' collaboration in self-organized teams. As our design-based research program continues, we will be working with the non-profit that runs this program to incorporate improved curriculum scaffolding in areas where we uncovered weaknesses. These results lead to questions about ways that the social tools could better support identifying how distributed expertise might be made more explicit both within and across teams in the classroom. Another question relates to how teachers might capitalize on emergent roles while at the same time finding ways to assign roles that are important but don't emerge. There is a tension here between the constructionist framework, goals for student-centered learning, and the need for the collaboration to be productive. Finally, there are logistic issues that must be resolved for groups to remain productively engaged and sustain both the doing and the learning (Blumenfeld et al., 1991). The example of version control is an issue of a logistical challenge that raises questions about how this can be supported so that it does not become yet another problem solving task that deters students from their goals. One area of future research in this project will aim to better understand how allowing students to self-organize might lead to stronger preferential identification with roles and tasks, and might contribute to the emergence of expertise recognition, and subsequently, the seeking of peer help, all of which may support emergence of conditions partially reflective of a community of practice in the classroom.

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