Contribution of Motivational Orientations to Student Outcomes in a Discover-Based Program of Game Design Learning

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Abstract: This paper explored relationships between middle school and high school teams of students’ motivational orientation and team outcomes in a guided discovery-based context in which students learned while designing web games. Teams of students with greater initial intrinsic motivation or a greater increase in intrinsic motivation during the activity had higher programming scores. Wiki activity contributed to outcomes. Age was negatively associated with outcomes indicating possibly the program is more conducive to middle school students. Findings contribute to scholarly debates on incompatibilities between discovery learning due to cognitive load, and self-determination theory.

Introduction
This paper reports findings from the 2009/2010 school year of a Constructionist digital literacy project being conducted with students and educators in the state of West Virginia involving a state-wide network of classrooms engaged in game design learning and purposeful social media use among youth. Middle school, high school and community college students (N = 386) enroll in a blended learning game design elective course offered daily, for 1 or 2 semesters, credit and a grade. The paper explores teams’ motivational orientation and active program work in relation to their learning outcomes, in the context of a guided discovery-based curriculum in which students and educators co-learn together in this social learning system.

Literature Review
Computational game making activities can enhance students’ meta-cognition, self-regulation, and computational thinking (e.g., Harel & Papert, 1991; Harel, 1991; Kafai, 1995; Kafai & Ching, 1998; Papert, 1980). Research supporting these findings has been conducted under the educative “framework for action” Constructionism (Papert, 1980; Harel and Papert, 1991). Constructionism draws upon both Piaget’s constructivist theory and Vygotsky’s social constructivist theory. Adherents design and implement learning innovations and environments that foster learners’ conscious creation of a meaningful, computational public artifact (e.g. a game), created and shared in a reflective, workshop environment of peer and expert-guided scaffolding (Harel and Papert, 1991). This study centers on a program of game design that employs a range of web 2.0 technologies including Flash and a wiki e-learning platform. In the co-learning model, the students engage in self-driven learning while their educators are still novices, using the provided resources. This activity can be characterized as guided discovery-based learning.

Discovery-based learning
While some argue that students can feel frustrated during discovery-based learning, others argue that students can enjoy it (Reynolds & Harel Caperton, 2011). Reynolds & Harel Caperton (2011) find contrasts in student perceptions of both enjoyment and challenge in the discovery-based context investigated here during the prior school year, given that occasionally novice learners must seek out learning supports to meet design needs in the moment. Kirschner, Sweller & Clark (2006) criticize “discovery-based learning” for creating excessive cognitive load due to lack of structure and distraction in the search process that reduces student motivation.

In contrast, self-determination theory (SDT, Deci & Ryan, 2008) argues that three primary constructs underlie intrinsically motivated human behavior, and are innate needs: the need for autonomy (to have choice and control over one’s life), for competence (to be effective), and for social relatedness (to feel connected to others, loved, and cared for) (Deci & Ryan, 2008; Ryan & Deci, 2000; Deci & Ryan, 1985). Level of autonomy afforded by a given environment, and the intrinsic and extrinsic motivational orientation of individuals play roles in their experience and fulfillment. Given the autonomy-supportiveness of the designed intervention, we propose the following hypotheses.

Hypotheses. H1. Teams with higher mean intrinsic motivation have higher team scores. Given the guidance, scaffolding and support from both teachers and non-profit staff, along with resources provided in the blended e-learning environment, we expect that even those students who are more controlled in their self-regulation style will also succeed and perform well in the program because the necessary supports have been provided for those who might need them. H2. Teams with more extrinsically-oriented self-regulation have higher team scores. Furthermore, in addition to the generalized holistic inventories outlined above, student motivation towards the specific contextual range of activities in which they engage might be related to subsequent team scores. H3. Teams with greater increases in motivation towards program activities have higher team scores. Finally, given students’ active engagement and use of a wiki, we explore the extent to which such activity may contribute to game design outcomes. H4. Teams with more wiki activity have higher team scores.
We also control for a range of other variables that might contribute to student outcomes, including student demographics and teacher demographics.

**Method**

**Attention.** In brief, a non-profit provided students and teachers digital learning supports via a wiki-based social media platform called MyGLife.org, in-person twice-annual teacher training, and ongoing virtual webinars with students and teachers. Individual students develop games, interacting with each other, teachers, and content resources on the wiki and in class, following a blended learning curriculum daily, for up to 90 minutes per session, across either a semester or a full year. The program applied many of the attributes of Constructionist design workshops described in Harel & Papert (1991) and Seely Brown (2005).

**Data sources.** Data sources have been combined into a single dataset and include pre- and post-program student survey data; educator progress reports bearing reflections and official student lists; student wiki activity metrics provided in MediaWiki e-learning platform, MyGLife.org; wiki user gallery and team pages identifying what individuals are on a given team; content analyzed student final game project files in Flash formats of .FLA and .SWF. Surveys were conducted online in August of 2009, January of 2010, and May/June 2010, depending on student participation modality (first semester only, second semester only, or full year). Links were distributed to students via each pilot location wiki, with educator administration. Research was conducted with full parental consent and child assent, and IR approval.

**Participants.** Out of 386 middle and high school student participants in the 2009/2010 school year, a total of 368 completed the pre-survey (95%), and 22 completed the post-survey (2%). A total of 6 middle school and 322 high school students participated. The drop off from pre-survey to post-survey is due to a range of factors, including student voluntary opt-out, student absences at the end of the school year, and student discontinuations in the program, changing of schools, etc. Findings reported here reflect those middle and high school students who completed both pre and post surveys. Participation was voluntary, and we acquired signed parent/guardian university IR-standard permission forms for all students.

**Dependent variables**

**Game activity.** For the dependent variable, we conducted content analysis of all teams’ final games; hence, team is the unit of analysis. We evaluate functionality built into students’ completed games (mechanics), as well as the game’s cultural content and design. The purpose for evaluating games is to better understand the range of game mechanics and messages students achieve in their particular school setting, identify patterns, and explore explanations. We also evaluate games to better understand the extent of knowledge students are gaining in the dimensions we explore.

**Coding theme development.** We define a 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 game files 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-rater 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, 0.81; Concept development evaluation, 0.75.

**Independent variables**

Independent variables were tested at three levels of analysis: school, classroom educator, and student game design team. All variables are from surveys unless otherwise noted. School level variables comprise grade level (middle school vs. high school) and student mean of parent education.

At the educator level, we aggregated educator time on task, calculating the average number of teaching hours spent by educators in an average quarter, using a standardized metric controlling for the N of progress reports provided and drawing upon quarterly self-reported teacher progress reports as the data source. We have also calculated the average number of the progress reports in each quarter and average teaching game design (including the present year). The number of students on a team ranged from 1 to 6. Thus, the individual data were aggregated to the team level and its mean and standard deviations were computed (Chiu, 2008; Chiu & Khoo, 2005). Individual student variables included participation months, grade, age, gender, motivation measures and psychological needs measures. All of these variables were self-reported by each student except participation months. While most variables were measured through surveys before the activity, intrinsic and extrinsic motivation and psychological needs variables were measured using previously validated instruments.
through both pre-activity and post-activity surveys (Lack & Deci, 2000; Williams & Deci, 1996) and indices were created (Oreskog & Sorbom, 2000). Alpha reliabilities for intrinsic and extrinsic motivation were 0.80 and 0.5, respectively. We also computed differences between pre- and post-variables for individuals, and then each team’s mean of these values were computed. Team mean change in motivation = mean of each team member’s (post-activity intrinsic motivation - pre-activity intrinsic motivation).

Indices of enjoyment (Ryan, Koestner, & Deci, 1991) towards a range of program activities within each of the “contemporary learning abilities” categories above were also created via factor analyses; for each category, combinations of at least 3 survey items reflecting enjoyment towards program activities achieved eigenvalues >1. Wiki activity indicates collaboration, project management, file sharing and publishing online. MediaWiki tools used provide an archive. The N of Wiki edits tell us how many times students edit and save pages. N of file uploads indicate how many project file uploads were made by students as an indicator of their productivity in game design. N of blog posts were also counted (students use blogs as a designer’s notebook, to reflect on process, free write, and exchange social messages). Each team game was coded for its genre: social issue, 1; educational, 2; entertainment, 3; mixed, 4; other, 5. Social issue games reflected a greater level of open and free choice by students, and include issues like poverty, teen pregnancy, nutrition, etc. Educational games were didactic and meant to teach the player something. These were more often linked to the core curriculum so that their creation was more structured (e.g., science games were required by some teachers because the game design class was offered as a supplement to a science class). Entertainment games often reflected pop culture themes and did not contain more serious content. Some games fell outside these categories and were labeled as other.

Analysis
We modeled the team scores of programming, design, game play, and concept with a multivariate outcome, multilevel model (Goldstein, 1995). A variance components model tested for significant differences at each level:

\[
\text{Team}_i^{\text{Score}} = \beta_{00} + \epsilon_{ij} + \eta_j
\]

The vector Team Score’s outcome variable \(y\) (Programming Design, Game play, or Concept) of team \(i\) in classroom \(j\) had a grand mean intercept \(\beta_{00}\) with team- and classroom-level residuals (\(\epsilon_{ij}\) and \(\eta_j\)). Explanatory variables were entered in sequential sets to estimate the variance explained by each set (Kennedy, 2008). School characteristics might affect teacher characteristics. Teacher characteristics might affect team members. All of these might affect team processes. Hence, we entered the variables as follows: school, teacher, team member characteristics, and team processes:

\[
\text{Team}_i^{\text{Score}} = \beta_{00} + \epsilon_{ij} + \eta_j + \beta_{0w}\text{School} + \beta_{0i}\text{Teacher} + \beta_{0j}\text{Team members} + \beta_{yj}\text{Team Actions}
\]

School: a school characteristics vector; high school and school mean parent education. Teacher: a vector of \(w\) variables at the teacher level; teacher gender, average teaching hours, average administrative hours, average self-learning hours, average word count of progress reports, and number of years teaching in Globaloría. We tested whether sets of predictors were significant with a nested hypothesis test (\(\chi^2\) log likelihood, Kennedy, 2008). Non-significant variables were removed. Team members: a vector of \(x\) team variables; number of team members, number of participation months, proportion of girls in team, mean age, mean self-reported grades, standard deviation (SD) of self-reported grades, mean parent education, the means and SD’s of motivation and enjoyment measures before game design (intrinsic motivation, extrinsic motivation, game enjoyment, search enjoyment, surf enjoyment, social media enjoyment, idea planning enjoyment, enjoyment of creating ideas, enjoyment of publishing, and basic psychological needs) and the means of the changes in the above motivation and enjoyment measures during game design. Team Actions: a vector of \(z\) team processes; game genres, mean and SD Wiki edits per month, mean and SD FLA project uploads per month, mean and SD SWF flash uploads per month, mean and SD blog writes per month.

We used multi-level mediation tests across the above vectors (Krull & MacKinnon, 2001). Then, we did a 2-level path analysis (Goldstein, 1995). We reported how a ten percent increase in each continuous variable above its mean was linked to the team scores (result = b * SD * [10% / 34%]; 1 SD = 34%). As percent increase is not linearly related to standard deviation, scaling is not warranted. We used an alpha level of .05. To control for the false discovery rate (FDR), we used the two-stage linear step-up procedure, which outperformed 13 other methods in computer simulations (Benjamini, Krieger & Yekutieli, 2006). The small sample of classrooms \((N = 18)\) limits identification of non-significant classroom-level results (for a 0.4 effect size at \(p = .05\), statistical power = 0.19; Konstantopoulos, 2008). We analyzed residuals for influential outliers.

Results
The participants created 139 games (28 individual games).

Explanatory Model. The results show substantial variance both across classrooms and within classrooms (programming: 43% across classrooms and 57% within classrooms; design: 60% and 40%; game play: 43% and 57%; concept: 52% and 48%; full tables provided in full paper). All results discussed below describe first entry into the regression, controlling for all previously included variables. Path Diagrams. Detailed path diagrams of standardized final 2-level model predicting team programming, design, game play...
and concept scores are presented as an appendix at the following link: http://www.isls.org. To aid reader understanding, the single path analysis is split into four separate diagrams, one for each outcome variable.

**Programming.** Teacher’s characteristics, team member characteristics, and team actions were linked to teams’ programming scores. If a teacher spent 10% less time on self-learning, his or her teams of students averaged 5% higher programming scores. Teacher’s self-learning hours accounted for 45% of the classroom-level variance and 19% of the total variance of teams’ programming scores. Teams of students who were one year younger on average scored 6% higher in programming. Meanwhile, teams with 10% higher mean intrinsic motivation before the game design activity scored 2% higher in programming. Teams whose members averaged a 10% increase in intrinsic motivation during the activity had 2% higher programming scores. Team member characteristics accounted for an extra 19% of the variance in teams’ programming scores. Teams that created mixed genre games averaged 28% higher in programming. Furthermore, teams with 10% more SWF flash uploads scored 2% higher in programming. Team actions accounted for an extra 7% of the variance in teams’ programming scores.

**Design.** Team member characteristics and team actions were linked to design scores. Teams whose members’ pre-survey variation of enjoyment of the activity ‘brainstorming and planning your game’ exceeded the mean by 10%, had 1% higher design scores. Team member characteristics accounted for 9% of the variance in teams’ design scores. Teams that created mixed genre games averaged 25% higher design scores, and teams with 10% more SWF flash uploads had 2% higher design scores. Team actions accounted for an extra 18% of design score variance.

**Game play.** Teacher gender, team member characteristics, and team actions were linked to game play scores. Teams taught by female teachers averaged 34% higher game play scores than those taught by male teachers (model 1). Teacher gender accounted for 50% of the classroom-level variance and 21% of the total variance of game play scores. Teams of students who were one year younger on average had 4% higher game play scores (model 2). Meanwhile, teams whose self-reported grades averaged one letter grade above the mean had 9% higher concept scores. Teams whose members’ pre-survey variation exceeded the mean by 10%, in the area of enjoyment of the activity ‘brainstorming and planning your game,’ had 2% higher game play scores. Moreover, teams whose members’ variation in enjoyment of the activity ‘brainstorming and planning your game’ before the activity exceeded the mean by 10% had 3% higher game play scores. Team member characteristics accounted for an extra 18% of the variance in teams’ game play scores. Teams that created mixed genre games averaged 22% higher game play scores (model 3). Furthermore, teams with 10% more FLA project uploads had 2% higher game play scores. Team actions accounted for an extra 6% of the variance in teams’ game play scores.

**Concept.** Team member characteristics and team processes were linked to teams’ concept scores. Teams whose members’ variation in enjoyment of the activity ‘brainstorming and planning your game’ before the activity exceeded the mean by 10% had 2% higher concept scores (model 2). Teams whose basic psychological needs before the activity exceeded the mean by 10% had 1% higher concept scores. Meanwhile, teams with 10% less variation in team members’ idea planning enjoyment before the activity had 1% higher concept scores. Team member characteristics accounted for 11% of the variance in teams’ concept scores. Teams that created educational or mixed genre games had 20% or 44% higher concept scores (model 3). Furthermore, teams with 10% more FLA project uploads had 3% higher concept scores. Team processes accounted for an extra 32% of the variance in teams’ concept scores. Other variables (notably, parent education) did not show significant effects. Mediation tests showed no significant mediations across significant explanatory variables.

**Discussion**

Unlike extrinsic motivation, intrinsic motivation is related to team programming outcomes, supporting H1 but not H2. For the computational activities that required resourcefulness in finding support resources (especially for novice educators), this guided discovery-based program of learning may support the autonomous natures of students with intrinsic motivational orientations. The positive intrinsic motivation results support self-determination theory (e.g. Ryan & Deci 2000) and suggest that the Globaloria program’s affordance of perceived autonomy and actual opportunity for autonomous engagement aids fulfillment of this basic psychological need for intrinsically motivated students.

Teams with greater variation in their members’ enjoyment of the activity ‘brainstorming and planning your game’ had higher design, gameplay and concept scores, showing some support for H3. Past case study research of game design processes (e.g. Reynolds, 2010) indicates that students often self-organize into the following team roles: programmer, designer, researcher of info for the narrative concept, and project manager. While team roles are shared, shift over time, and are predicated on N of students, pre-program variation in this category (some high and some low) may indicate a variation in preferences for certain roles, which may have contributed to more felicitous team dynamics and game design processes. This is consistent with past results showing that teams with a subset of individuals who identified with and enjoyed this over and above others had more coherent storylines and smoother design processes.

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Teams with more wiki activity had higher team scores, supporting H4. These results suggest that using wiki resources and the wiki platform to share files and manage their project and process, contributes directly to outcomes. Also, younger teams of students outperformed older teams of students, possibly because younger found the activities more engaging. At the teacher level, results of a negative contribution for self-learning hours may indicate that students of more novice educators who required more self-study time did not perform as well. These results lead to practical recommendations for the organization, as well as offering insight into the extent to which critiques on discovery-based learning may need to be qualified in relation to autonomy. For instance, the autonomous versus controlled motivational orientation instrument could be used up front to identify students who may need more guidance and structure. This may require a greater teacher training and preparation. Further, the wiki may need to be further optimized to help students find and use resources.

One limitation is that this data set only included assessments of teams. Future studies can also include assessments of individuals. More research is needed to understand the contribution of implementation context variables in the intervention that our study does not precisely measure (e.g., game subject focus: a class’s integration with core curricular domain classes; sequence of learning activities and varying implementation contexts by school) and other individual- team- and teacher-level variables that might influence student outcomes. We will analyze the data in the current school year, which includes such additional variables. Further we have proposed grant funding to conduct qualitative case study research in West Virginia schools to better understand the mechanisms of teacher, team, and curriculum dynamics, and generate new hypotheses. These results may extend beyond the learning sciences into the larger arena of scholarship on socio-technical system design in general, as individual intrinsic motivation may contribute to the success of user experiences in socio-technical environments when such environments are less-structured and require autonomous engagement. This finding could hold importance given the growing level of expectation in our society for individuals to have develop digital expertise and actively use technology in order to participate as citizens.


