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Learning with Minecraft and Kodu: Examining Complex Problem-Solving Strategies

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Abstract: The purpose of this research is to examine how game-based learning coupled with the problem-based learning pedagogy affects students' ability to solve complex, ill-defined problems. This study examines two cases of digital game-based learning in a secondary school in Korea: Social Studies class where students learned the complexity of urban planning with Minecraft; Science class where students learned the topic of air pollution with Kodu. The students were presented with open-ended problems that they discussed and solved as groups. Discourse data was transcribed and content-analyzed according to the coding framework on the patterns of complex problem-solving strategies. Overall, we found that game-based learning with Minecraft and Kodu, coupled with a PBL curriculum, can help students in tackling complex, ill-defined problems by improving their use of models and planning practices. In conclusion, we discuss the implications of this study concerning the potential and challenges of digital game-based learning in preparing students for the changing world.

Keywords: Digital game-based learning, problem-solving, Minecraft, Kodu

1. Introduction

The rapid pace of technological and social change that has characterized the first few years of the twenty-first century has spurred the need for timely education reform. The next generation of students can expect to face problems that are ill-defined and complex and that require students to develop habits of regular, lifelong re-education. School-based education, reacting to these changing student needs, must particularly account for the massive change brought on by digital technologies. As general information is readily available to anyone with an Internet connection, students must instead learn to navigate digital spaces and resources, teaching themselves sufficiently to use tools that are necessary to solve new problems. Collins and Halverson (2009) characterize this difference in terms of content coverage and individual knowing versus relying on outside sources given the knowledge explosion. Curricula, they argue, should no longer aim to cover all of the content within a domain and assess individuals in terms of what knowledge they have in their head. Instead, classrooms could encourage students to understand how to identify, find, and use the external resources they need to solve their problems.

As institutional reforms have begun to emerge driven by changing national policies (e.g. America COMPETES act), priorities are also shifting from learning as content acquisition to helping students develop life-long learning. Schools and educators are increasingly pressured to adapt new approaches to teaching and learning in order to remain relevant and useful. At the core of these new approaches is a need to change school cultures, practices, and technologies of learning. Digital technologies like video games have, for many educational reformers, served as an interesting and potentially powerful motivator for such reform. Games, researchers argue, can attract and create communities of people who share common interests, work together across digital networks to solve complex problems, and teach themselves necessary knowledge and skills in order to successfully and effectively play games (Gee, 2003; Shaffer, Squire, Halverson & Gee, 2005). New approaches like game-based learning bring with them unique challenges, however. For example, learning with games might mean that students take a more central role in classroom activity, playing and directing their own learning. During game play, teachers may also change roles, shifting position from the authoritative source of classroom knowledge to that of a facilitator, helping students reflect on and synthesize game-related knowledge. New technologies like games may be useful for addressing contemporary and changing learning needs. These new technologies require support and research in order to ensure effective and appropriate use.

With this backdrop about the changing landscape of K-12 schools and the potential of game-based learning, the purpose of this paper is to present a case study where students were engaged to learning with Minecraft and Kodu. We were interested in how game-based learning coupled with the problem-based learning pedagogy affects students' ability to solve complex, ill-defined problems.

1. Method

1.1. Research Context

This study was conducted at a private all-boys middle school located in a metropolitan area in South Korea. The school has been implementing problem-based learning (PBL) as a school-wide pedagogical approach, and the use of digital learning solutions has been a part of this effort. Students and teachers in the 7th grade (age 13-14, N=124) were selected as the main participants of this research project. Teachers administered lessons of their own design as well as lessons co-designed with researchers in order to achieve curricular and research goals.

This paper presents cases of two classrooms where students were engaged to learn with game-based learning approaches. The first case is a Social Studies class where students learned about the complexity of city planning through the PBL lessons that incorporated Minecraft, which is a sandbox game where players can build constructions with cubes in a 3D world. Over the course of this PBL activity, the students did research about famous cities around the world, then gathered information about the problems that their own city was facing, such as traffic or water management. As shown in Figure 1, the students then were instructed to develop a plan for a city that they would like to live in. The planning phase was done with pencil and paper, and the plans were then implemented in Minecraft. The students presented their model cities at the end of the unit. The goal of the exercise was for the students to gain a more holistic understanding of the city and its problems. The students graded themselves and each other on their understanding of the problem, the completeness of their research, and the quality of their presentation. As all the classes in the 7th grade used Minecraft, we did not set a control group for comparison.

Figure 1. Student Activity with Minecraft in Social Studies

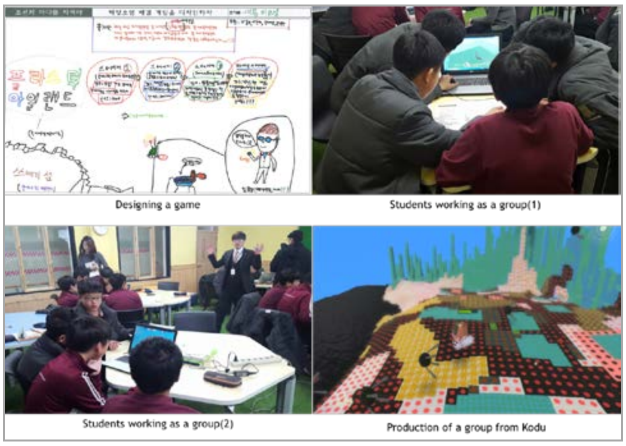

Figure 2. Student Activity with Kodu in Science

The second case reported is a Science class that similarly incorporated game-based learning into the PBL curriculum. The game technology used in the Science lessons was Kodu, which is a 3D digital game design environment that uses iconographic, drag-and-drop commands instead of scripts. Though the environment is relatively limited compared to other digital game development environments such as Unity, it is a useful tool for students with little programming background who are interested in developing their own games. The in-class PBL activity (see Figure 2) involved student groups researching the topic of "Ocean Pollution", drawing a mind-map of the various factors, and then creating a game in Kodu based on their initial game sketch. For the second case, we were able to set another class of students, who had not undergone a Kodu activity, as a control group.

1.2. Data Collection and Analysis

Our main research aim was to examine the impact of Minecraft and Kodu within the PBL curriculum on students' complex problem-solving skills. In particular, we were interested in understanding how students approached and reasoned their way through complex problems. To this end, we developed open-ended problems for them to discuss and solve in groups. The open-ended problem was similar to the problems that the students had to solve during their PBL lesson. For Social Studies, the students were given a problem about transportation and related social issues. The problem involved a decision between two possible ways to build a new subway line through a city. Because each route had different tradeoffs, the problem, administered in a focus group setting, was intended to elicit student discussions about factors that might be important to consider and illuminate how students approached complex problems. Nine groups of students with 4-5 members from two classes participated in this problem-solving activity. For the Science class, the students were presented with a problem where they need to identify three major causes of air pollution in Korea, and propose the design of systems or devices to address them. The students were split into eight groups, and their discourse data during the problem-solving process was audio-recorded and transcribed for analysis.

We conducted qualitative content analysis of student discourse captured during the problem-solving process. The analytical framework that we developed to examine students' problem solving strategies in this open-ended problem was based on two sources. First, the coding framework was based on Beckett and Shaffer's (2005) investigation of the outcomes of an urban planning educational game, which employed an open coding method to generate codes from student interviews and their artifacts. The codes they developed were interconnectedness, understands complexity, planning practices, use of model, and open-endedness. Second, similar to Beckett and Shaffer (2005), we used a grounded approach (Corbin & Strauss, 2008) to identify three more (making a total of eight) problem-solving strategies that students used while solving a complex thinking problem. These codes emerged using a constant comparative method (Lincoln & Guba, 1985) from transcripts. As shown in Figure 3, the final codes developed were divided into epistemic and practical categories with the eight codes of problem-solving strategies: 1) use of model, 2) planning practices, 3) understanding complexity, 4) inference, 5) adaptation, 6) making consensus, 7) open-endedness, and 8) interconnectedness. Two researchers assigned codes to discourse statements, and an inter-rater reliability analysis for the codes was performed to determine consistency between the coders, calculating Cohen's Kappa. The Cohen's Kappa inter-rater reliability coefficients for the eight codes range from .68 to .85, indicating satisfactory agreement between the raters (Cicchetti, Lee, Fontana & Dowds, 1978).

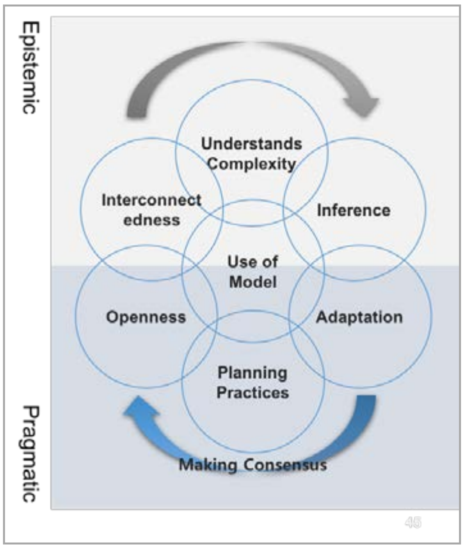

Figure 3. Patterns of Problem-solving Strategies

2. Results

2.1. Social Studies

The overall frequency of the strategies utilized during the problem-solving process in the Social Studies problem ranged from 43 to 788 across the nine groups (see Figure 4). "Use of model" was the most frequently used strategy, followed by "Understanding complexity," "Inference," "Planning practices," and "Interconnectedness." In addition, "Adaptation," "Making consensus" and "Open-endedness" were utilized as problem-solving strategies at low frequencies. These results indicate that students who learned with Minecraft used a variety of strategies to solve the open-ended problem and could make inferences based on the complexity and interconnectedness of the given problem. The frequency of using those strategies per group is indicated in Table 1.

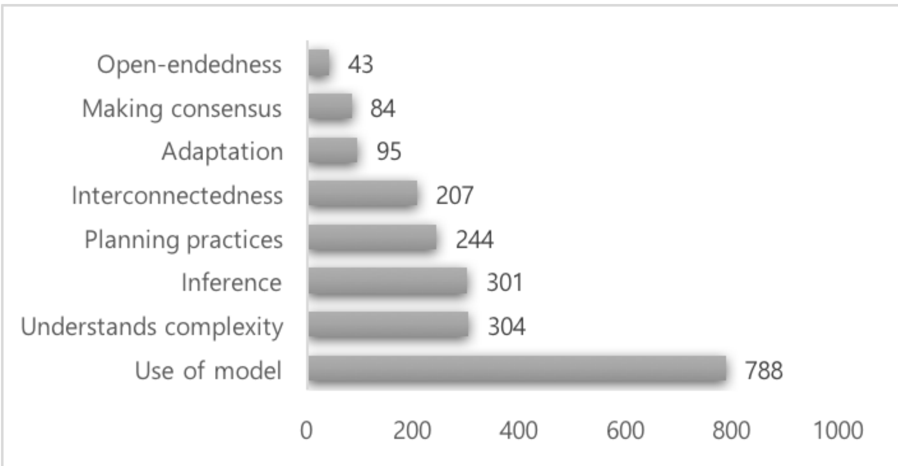

Figure 4. Patterns of Problem-solving Strategies in Social Studies

Table 1: Percentage (%) of problem-solving strategies used per group in Social Studies.

	G1	G2	G3	G4	G5	G6	G7	G8	G9
Understanding complexity	20.6	26.5	23.3	12.9	23.5	13.6	11.5	8.4	16.4
Interconnectedness	19.1	36.8	11.8	7.2	19.9	12.8	7.6	4.5	7.2
Use of model	44.1	116.2	29.0	36.6	41.9	37.2	51.0	34.1	39.5
Inference	11.8	16.2	15.1	18.5	8.1	15.9	8.3	13.8	20.5
Adaptation	0.0	2.9	6.5	4.0	1.5	3.5	2.5	11.9	1.5
Making consensus	4.4	16.2	8.6	2.0	0.0	1.9	3.2	5.8	4.1
Planning practices	0.0	22.1	5.7	17.7	5.1	11.2	14.0	16.4	8.2
Open-endedness	0.0	5.9	0.0	1.0	0.0	3.9	1.9	5.1	2.6
Total (absolute number)	68	165	279	497	136	258	157	311	195

Based on the density of utilizing the problem-solving strategies, we selected one group (Group 4) for further analysis. Group 4 was chosen because the students showed the highest level of engagement during the discussion. Throughout the discussion to solve the given problem, this group constantly utilized the “Use of model” strategy to solve the given problem while sometimes using “Making consensus”. In the initial phase of the discussion, “Understands complexity” and “Interconnectedness” were the most used strategies, followed by “Inference” and “adaptation” as the discussion progressed. In the final phase of the discussion, this group began to utilize “Planning practices” and “Openness” as problem-solving strategies. The group’s patterns of problem-solving strategies could be described as progressing from epistemic to pragmatic. This result implies that, to engage in a meaningful problem-solving process, a combination of a variety of problem-solving strategies should be used throughout the process, and that students generally move from thinking abstractly about the problem to addressing more concrete and contextual issues.

2.2. Science

The whole frequency of each strategy utilized during the problem-solving process ranged from 62 to 471 across the groups (see Figure 5). Differing from the results of social studies, “Planning practices” was the most frequently utilized strategy, followed by “Use of model,” “Making consensus,” “Adaptation” and “Inference.” “Interconnectedness” and “Open-endedness” showed relatively low frequencies during the problem-solving discussion. The frequency of utilizing each strategy per group, for both experimental and control conditions, is shown in Table 2.

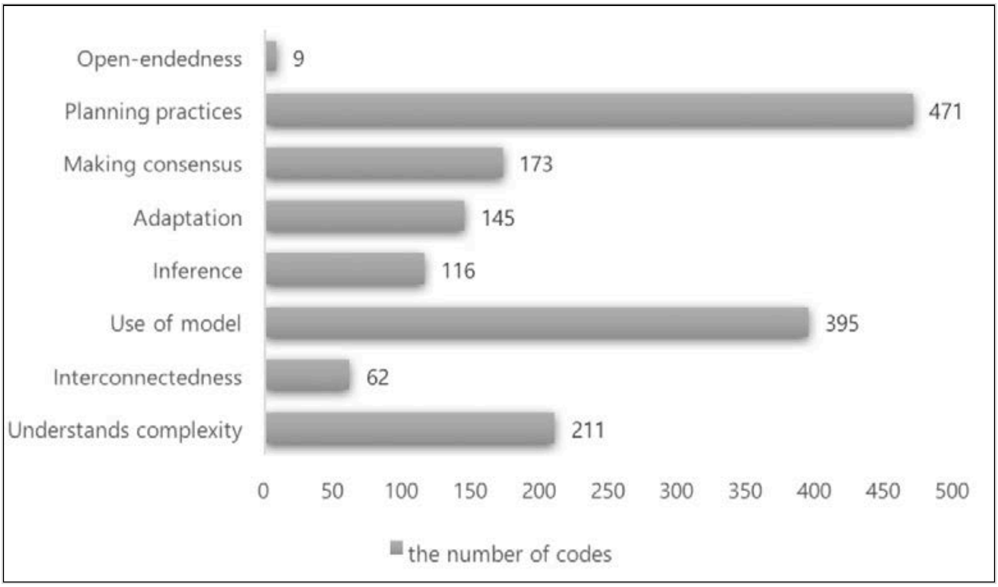

Figure 5. Patterns of Problem-solving Strategies in Science

Table 2: The percentage (%) of problem-solving strategies used per group in Science.

	Experimental				Control			
	EG 1	EG 2	EG 3	EG 4	CG 1	CG 2	CG 3	CG 4
Understanding complexity	5.6	13.6	9.7	5.5	16.7	22.0	11.6	21.0
Interconnectedness	4.3	5.4	1.9	2.3	3.8	8.0	0.0	5.4
Use of model	21.5	31.5	18.9	38.3	28.4	40.0	10.9	21.3
Inference	11.2	9.7	2.9	0.0	5.3	0.0	13.2	8.9
Adaptation	14.2	5.8	12.1	2.3	14.8	0.0	8.5	6.0
Making consensus	13.7	5.8	14.6	5.5	16.7	12.0	9.3	8.6
Planning practices	29.6	26.1	39.8	46.1	12.9	18.0	46.5	28.9
Open-endedness	0.0	1.9	0.0	0.0	1.5	0.0	0.0	0.0
Total (absolute number)	233	257	206	128	264	50	129	315

Note: EG = experimental group, CG = control group

Next, we examined the differences in utilizing problem-solving strategies between the four experimental groups who had a learning experience with the digital design tool of Kodu and the four control groups who had not. Figure 6 shows that the Kodu groups utilized some strategies such as “Planning practices”, “Use of model”, “Adaptation” and “Open-endedness” more frequently than the control group did. To be specific, the Kodu groups utilized “Planning practices” the most, followed by “Use of model”, “Making consensus”, “Adaptation” and “Understanding complexity”. The largest difference between the experimental and control groups appeared to be “Planning practices”, “Understanding complexity” and “Use of model”. This result indicates that the experimental groups that learned with Kodu applied more practical (rather than epistemic) problem-solving strategies and more frequently utilized those strategies throughout the problem-solving process than the control groups did.

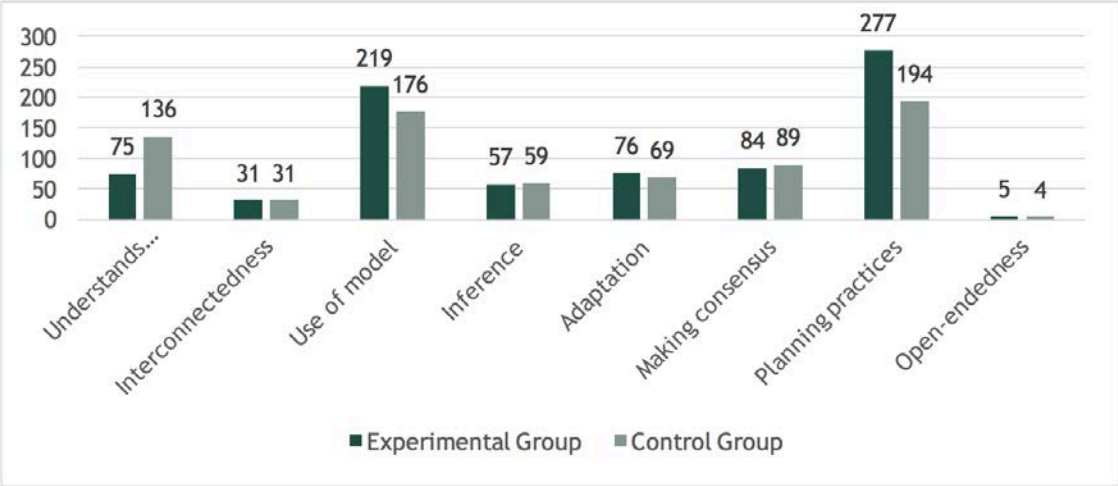

Figure 6. Comparison between Experimental and Control Groups in Utilizing Problem-solving Strategies in Science

3. Discussion and Conclusion

The findings from this study are important in two ways. First, they exhibit an approach for looking at how students solve problems whilst using digital, game-based tools, suggesting a useful framework for evaluating the process of problem solving rather than examining particular solutions. Students' could be characterized as applying pragmatic, context-specific methods as well as more abstract, epistemic methods as they work toward finding a solution. Further research may validate the quality of these pragmatic and epistemic student processes by, for example, relating the practices to the solutions students generate or to future problem solving processes and successes.

Second, the findings in this study suggest that game-based learning with Minecraft and Kodu, coupled with a PBL curriculum, can help students in tackling ill-defined, complex problems by 1) improving their use of models and planning practices, 2) providing heuristics for solving similar problems (e.g., decomposition), and 3) orienting students toward finding flexible rather than fixed solutions. As game design software has trended in recent years toward increasing approachability, this study's findings show how such software be useful as tools that enable students thinking through and designing solutions to real-world problems. Combined with recent calls for game design as a means to improve students' computational thinking and participation (Kafai & Burke, 2016), this work exhibits another affordance for using game design for education.

While problem solving has previously been an important topic for math (Polya, 2014) and engineering (Sharp, 1991), it has been less well-addressed as a topic in new digital technologies. Students will inevitably be confronted with problems that are ill-defined and wicked, especially as networked digital technologies and globalized economies create issues that are interdependent and complex. As pedagogies and designs for improving education must addresses these changing educational demands, understanding games and game design environments can be useful tools for enabling student problem solving activities, as they can provide sophisticated, sandbox-like environments within which students may exercise and exhibit authentic problem solving.

Using these digital tools is not without its challenges. Authentic, ill-defined problems are often comprised of content that students had not previously encountered or anticipated and preparing students to confront these problems means focusing less on the solutions that they produce and more on the processes and means that they use to produce their solutions. Developing, supporting, and assessing students' problem solving is difficult in that didactic problem solving activities must be specific enough to be assessed, but generalizable enough to be adaptable to new contexts. Identifying important student-student and student-teacher interactions for example, has been an important issue in effective mathematics problem solving practices (Lester, 1994) and remains an important issue for digital, game-based tools.

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