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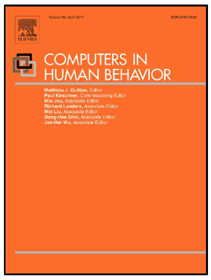

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Highlights

- Game design promotes problem-solving skills in special needs young people
- Ill-structured problem solving is supported by free design more than directed design
- Free design promotes representation, planning and evaluating characteristics for problem solving
- Directed design promotes executing characteristics for problem solving

Problem Solving through Digital Game Design: A Quantitative Content Analysis

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Abstract: Project Tech engages secondary students (ages 14 to 17) in the process of digital game design in a variety of in-school, after-school, and secure settings. The goal of Project Tech is to leverage students' interests in games and design to foster their problem-solving in a supportive environment where they learn to create games about a social issue they have experienced personally. The present study compares the in-school special needs version of Project Tech (n=11) to examine problem solving. Students enrolled in Project Tech were guided in the process of designing digital games aimed at teaching younger students (ages 12-15) about social issues facing teenagers. A quantitative content analysis was conducted on 35 iterations of a directed design game and 35 iterations of a free design game created by special needs young people and director notes. The purpose of the study was to draw from the game iterations a list of empirically grounded problem solving attributes that are associated with digital game design in a special needs classroom. The findings of the study resulted in the understanding of problem solving with special needs young people in four areas: representative characteristics, planning characteristics, executing characteristics and evaluation characteristics.

Keywords: special needs education; digital game design; problem solving; quantitative content analysis

Problem Solving through Digital Game Design: A Quantitative Content Analysis

Abstract: Project Tech engages secondary students (ages 14 to 17) in the process of digital game design in a variety of in-school, after-school, and secure settings. The goal of Project Tech is to leverage students' interests in games and design to foster their problem-solving in a supportive environment where they learn to create games about a social issue they have experienced personally. The present study compares the in-school special needs version of Project Tech (n=11) to examine problem solving. Students enrolled in Project Tech were guided in the process of designing digital games aimed at teaching younger students (ages 12-15) about social issues facing teenagers. A quantitative content analysis was conducted on 35 iterations of a directed design game and 35 iterations of a free design game created by special needs young people and director notes. The purpose of the study was to draw from the game iterations a list of empirically grounded problem solving attributes that are associated with digital game design in a special needs classroom. The findings of the study resulted in the understanding of problem solving with special needs young people in four areas: representative characteristics, planning characteristics, executing characteristics and evaluation characteristics.

1. Introduction

Despite the widely recognized importance of application as a higher-order thinking skill, during formal schooling students do not get many chances to design their own solutions to abstract problems that they face in daily life (Jonassen, 2000; Scribner & Cole, 1973). One reason for this is that schools place a heavy emphasis on covering and delivering content knowledge. In addition, schools frequently introduce application as a concrete solution to a concrete problem (Jonassen, 1997, 2000) rather than a process that builds from a series of events such as happens in real life. Practice with well-structured problems (i.e., problems with one solution) do not help students gain skills to solve real-world problems, which are characterized as ill-structured, or wicked (Brown, Harris, & Russell, 2010; Buchanan, 1992) and have more than one solution and often are offshoots from other problems and lead to even more problems (i.e., poverty leading to lack of healthy food leading to malnutrition). Students with special education needs (SEN) face dual difficulties with building higher-level skills; they are both more likely to have lower reading and math abilities (Friend, 2013; Smith, Polloway, Patton, Dowdy, & Doughty, 2015) and their social awareness, self-esteem and social skills are also less developed than their peers.

Because of shortcomings of formal education in teaching application through ill-structured problems, researchers and educators have sought alternative ways of teaching students complex problem solving skills first using programming (Papert, 1980) and as technology has gotten more user friendly, game-design (Kolb, 2014; Murray, 2016) and software engineering. Recently, using game-design as a context to teach problem solving has received interest from researchers (Akcaoglu & Koehler, 2014; Ke, 2014), but empirical support of these tasks has been slow to emerge.

Game design has particular advantages over other design-based activities, most importantly students in secondary school are familiar with video games (Granic, Lobel, & Engels; 2014). Game design also offers multiple roles such as storytelling, programming, artwork, sound and mechanics (Dickey, 2006; Sung & Hwang, 2013). This allows teamwork and promotes problem solving skills directly aimed at application of these skills (Kafai & Burke, 2015). In this paper, building upon previous work (Ruggiero, Garcia-Hurtado, & Watson, 2013), we aim to provide empirical support for the impacts of learning game-design on special needs students' problem solving.

2. Background

2.1 Problem-solving

Problem-solving is reaching a desired goal state from a given state by overcoming barriers in between and when there are no obvious ways of reaching the end goal (Mayer, 1992). Using this definition, problem refers to situations when a problem solver has a goal but does not have obvious methods to get there. The act of design, where the designer's goal is to create something that crosses the gap between problem and goal can be considered as an example of an ill-structured problem situation (Simon, 1973).

The process of problem-solving involves activation of important cognitive skills, and therefore, problem-solving is often synonymous to thinking (Mayer, 1992). From a cognitive perspective, the problem-solving process involves representing, planning, executing, and evaluating (Jonassen, 1997). Representation refers to converting the external problem to an internal mental picture, when this occurs it can be equated to understanding the scope of the problem. Planning is the process of breaking a problem into parts and coming up with a solution. Execution is acting on the plan, and evaluating refers to checking to see if the execution helped solve the problem.

2.2 Methods of teaching problem solving

Researchers (Polya, 1981; Snyder & Snyder, 2008; Woods, 1975) have identified methods that have proven to be effective when teaching problem solving. Some of these instructional methods can also be used with special needs populations (Agran, Blanchard, Wehmeyer, & Hughes, 2002; Case, Harris, and Graham; 1992) and lead to meaningful learning by helping students to apply their learning to solving problems (Boggiano, Flink, Shields, Seelbach & Barrett, 1993; Leary, Walker, Shelton & Fitt, 2013). Meta-analyses (Dochy, Segers, Can de Bossche & Gijbels, 2003; Hembree, 1992) have provided educators and researchers with examples of effective methods of teaching problem solving. One method found to be effective with special needs students is to focus on teaching basic skills in order to give them more cognitive power moving from low-level to higher-level skills (Kroesberge & Van Luit, 2003). This load reduction model creates a scaffolded model for introducing more complex problems.

2.3 Problem types

There are two types of problems, structure and ill-structured. Structured problems have one answer and are based on cognitively based processes (e.g. two trains leave their stations 180 miles apart, one is going 70mph and one 80mph, when do they pass each other?). Ill-structured problems, or wicked problems (Buchanan, 1992) are problems that do not have one solution (e.g. Somalian refugees continue to flee the horn of Africa in record numbers, what is the best way to meet the needs of the refugees?). Structured problem solving can be thought of like a recipe and by following the prescribed algorithm an answer will be reached (Shin, Jonassen & McGee, 2003); ill-structured problem solving is non-zero sum and requires addressing bigger issues over winning or losing (Head & Alford, 2015). Research (Collins, Sibthorp & Gookin, 2016; Reed, 2015; Savery, 2015) has demonstrated that teaching with ill-structured problems increases student understanding of world issues (Bulu & Pederson, 2010; Frigotto & Rossi, 2015) and enhances citizenship (Dugan, Bohle, Woelker & Cooney, 2014). Little research has been conducted on ill-structured problem solving with special needs young people (Kolodner, et. al, 2003; Yssledyke, 2005) and current literature illustrates that promoting ill-structured problem solving with special needs students requires much scaffolding and often is not successful (Belland, Walker, Kim & Lefler, 2016; Ferretti & Okolo, 1996; Kameenui & Carnine, 1998; MacArthur, 2009; Seo & Bryant, 2009).

2.4 Research on using game design to teaching problem solving

A little researched way to teach ill-structured problem solving is game design (Dondlinger & McLeod, 2015; Ruggiero, 2016). Current research has demonstrated that game design can provide both structured and ill-structured problems (Ackaoglu, 2014; Hunicke, LeBlanc & Zubek, 2004) that requires learners to move through the representation, planning, execution, and evaluation stages of problem solving. Hwang, Wu, and Chen (2012) demonstrated a connection between web based problem solving and games while Dickey (2006) examined the process of game design as a methodology for design based research. While current research has a significant gap in empirical studies that explore game design as a way to measure problem solving skills, there are studies that have focused on other factors. Kafai (1996) addressed the idea of constructionism and the role of design for young people in learning environments while Ke (2014) examined design based learning for young people creating video games. Further research (Ackaoglu, 2016; Ackaoglu & Koehler, 2014; Gee & Tran, 2015; Kafai & Burke, 2015) has explored the role of learners in the game design process and the educational benefits for structured problem solving.

3. Study context: Project Tech inclusion program

The Project Tech program, the context for this study, is a pilot program sponsored by the School of Education at a mid-sized university in Southwest England in cooperation with a local inclusion unit at a secondary school. Learners attended a six-month game development program hosted in partnership with the special education department. The purpose of the program is to use social skills features in a game development intervention to promote academic learning. More specifically, game development means that learners create two video games through representation, planning, execution and evaluation. Thus, we are examining how special education students use problem solving to learn how to develop a game. The program focuses on the learners using problem solving skills and working with authority figures as equal stakeholders. Students attended workshops designed to teach game development. Each session, learners interact with each other and program directors to brainstorm, plan, and implement game design. In the program's cooperative learning model, through game development, students and directors learn together. The learning procedures include: (a) self-led learning, in which students and educators problem solve through their own independent game development process, (b) peer-to-peer learning, in which learners work with each other on game creation scenarios, and (c) expert-guided learning, in which directors help scaffold learning and solve problems on demand. These learning events lead to 1) a directed design game that all students complete following the same steps, and 2) a free design game that students plan, design and develop on their own.

When designing the Project Tech curriculum, we paid specific attention to incorporating well-known instructional methods for solving problems in social contexts, as teaching problem-solving was one of the main goals. In the next section, we summarize the overall structure of the Project Tech curriculum, as well as some of the instructional methods uses, in order to give the readers a feel of the instructional context of the Project Tech programme. Readers interested in a broader discussion of the theory behind the design of the curriculum, or a more detailed account of instruction can find more elsewhere (Ruggiero, Hurtado, and Watson, 2013; Ruggiero and Green, 2016).

3.1 Pedagogical principles

Two main pedagogical approaches that guided the design and delivery of the Project Tech programme were guided discovery learning and social constructionism (Jonassen, 2000; Kafai & Burke, 2015; Kolb, 2014). During the free design of their games, learners were encouraged to work freely and discover knowledge (Brown & Campione, 1994; Martin, 2015). The guided discovery approach was chosen over pure discovery as learners required guidance and feedback during the game-design process. The reason for this choice was because our learners have learning difficulties that made pure discovery too cognitively taxing given the lack of any experience in game design for this group of students (Kroesbergen & Van Luit, 2003). This support helps alleviate the cognitive burden on the learners and benefits the learners more, creating a safe place for asking questions and forming relationships (Martin, 2015).

During the process of guided discovery learners were encouraged to bring their own experiences to the game design process. Social constructionism is a sociological derivative of constructionism- the idea that learners construct meaning about their reality by creating meaningful artefacts (Andrews, 2012; Dondlinger & McLeod, 2015). By building upon shared experiences, the Project Tech programme encourages learners to construct their own knowledge of game-design and produce socially meaningful and engaging artefacts: games (Akcaoglu, 2016; Brandt, 2006).

3.2 Project Tech Curriculum and activities

Our curricular goals included teaching special needs students problem-solving through game design. Although the goals of teaching game design were a natural outcomes of participating in Project Tech, in order to teach students problem-solving, the Project Tech curriculum and activities were shaped according to the social constructivist theories and problem-solving pedagogies. Specifically, the activities were designed to utilize two main methods of teaching problem solving: teach problem-solving skills directly and teach for understanding (Mayer & Wittrock, 2006). Based on these principles and curricular goals, two main types of activities were offered during Project Tech: directed design and free design. Game design activities were throughout the Project Tech programme and other activities, such as programming and artwork, were scaffolded from the first day and increased as learners gained more experience and confidence in game design.

The main goal of game design activities was to teach students the basics of the game design process through problem solving. During these activities leaners also learned background knowledge and skills in using the game design software and design skills that are necessary for creating digital games. This was based on the idea that learning the basic skills of game design would lower the burden on students' cognition and help them better focus on the later activities involved in solving ill-structured problems.

During game design activities, the learners were guided in creating a game (a two dimensional side scroller), through a series of directed sessions that were followed by free design sessions where learners worked in the same small groups and explored the concepts of game design by creating their own game. Also, during game design activities the learners got hands-on experiences in (1) systems thinking, by seeing how games are complex systems made up of intersecting decisions; and (2) game design, by creating their own games, which are also complex systems.

Problem solving activities were introduced in parallel to the digital game design activities. By the time the ill-structured problems were introduced, the learners had already become familiar with the computer software and had practiced the basic game design skills multiple times. The purpose of these activities was to give learners the opportunities to think more deeply about their free design game and pair the process of problem solving with the directed design. To do this the problem solving activities included group conversations about the problem scenario in the directed design (e.g., a story built on the social issue of cyberbullying), solving the problem by promoting the socially responsible choice and explaining the relationship among player choices presented in the scenario, and then creating a playable scene for a learner age 12 to 15.

During free design, director guidance was available in the form of working with the students on the steps to solve a problem. The guidance was provided in two specific forms: (1) an initial group conversation about the problem scenario, and (2) one-on-one guidance to individual teams when they struggled with the computer software or the design of the game, this happened rarely. For example, in the first directed design, the director presented the problem scenario, as well as elicited solutions from the entire group. During this process, the director guided the learners in following the steps to solve problems we had talked about: (1) understand the problem, and (2) plan the solution. Other effective methods for teaching problem solving were also used within directed and free design. For example, by using free design activities learners were able to tackle problems built on their own experiences rather than all completing the same scenario. This way, learners were given chances to work with specific problems and identify patterns while solving problems. Finally, the idea to use the computer software to recreate the problem scenarios was based on the idea that learners remember more when they create their own personal representations of the problems, connecting old and new knowledge, a generative method of teaching problem solving (Marsh, Bink & Hicks, 1999).

In addition to activities purely focusing on game design and problem solving during Project Tech learners were also offered activities where the main task was to participate in breakout sessions on changing current games to games about social issues. By analysing the structure of a given game, during the breakout sessions, the learners identified the relationship between the content and the game mechanics, and made necessary changes to create a socially focused game. It should be added that although not explicitly integrated these breakout sessions were integral to the game design process. Therefore, the learners found many opportunities to incorporate breakout sessions in their free design.

During free design the learners were asked to create a game of their own choosing. These free design sessions were integrated throughout Project Tech and scaffolded to support learners as they gained skills in game design and problem solving. These activities provided learners with the chance to work in smalls groups to create games focused on a social issue effecting teenagers that they personally valued. Providing the learners with free design sessions in parallel to directed design throughout the programme was important because it both involved elements from parallel activities (game design and problem solving) and contextualized these skills in a meaningful and personal context such as creating their own games.

During free design, as in directed design, the learners got chances to practice their problem-solving skills. It was a common occurrence for learners to decide how to balance the amount of interactions in a game based on the capacity of their test player to complete each level. In other words, they were constantly reminded to be mindful about how much cognitive load they were putting on their peers and how they can make the right design decisions where there is a minimal compromise. For example, after realizing that their game world was too complex for the player to navigate, one group decided to make certain characters in the game helpful navigators that direct the player to the next checkpoint, and removed elements that were not crucial to the gameplay. By solving this problem, the group managed to help the player while creating a useful game mechanic without compromising the integrity of their game.

4. Purpose

The purpose of this study was to provide empirical support for the positive impacts of learning game design on learners' problem solving skills. We aimed to investigate how learners' problem solving skills differed between directed and free design in Project Tech where they practiced their problem solving skills through game design activities for six months.

5. Method

5.1 Participants and Process

A total of 11 students participated in the current study. The average age of students in Project Tech was 15, ranging between 14 and 17. Two participants were female and 9 were male. All students were in a Key Stage 4 provision for students of lower academic ability who are not undertaking exams in the full range of GCSE subjects. All of the students have general low attainment with additional needs such as dyslexia, autism, and ADHD.

The 11 participants were broken into five groups. Each group worked on a directed design game and a free design game in parallel. At the beginning of each workshop (n=30) teams would present their current status and then work on the directed game for 40 minutes. The directed game design followed a particular curriculum (for more information please see Ruggiero, Hurtado and Williams, 2013) and each session was calibrated to maximize game design time and skill acquisition. This included a short introduction to the workshop skill (e.g. character artwork, moving from level to level) and then each team would work on that skill for the allotted time. The teams then worked on their free design games for the following 40 minutes. The last five minutes of each session were used to collect the iterations of each game from that day and to tell the young people what we would be doing in the next workshop session. At the end of the study 7 iterations from each of the 5 directed design games (n=35) and 7 iterations from the free design games (n=35) were chosen to analyse for problem solving skills related to this study (Figure 1). The iterations were selected based on the schedule of workshops; the school calendar controlled the frequency of workshops and the selected iterations were all approximately three weeks apart.

Figure 1. Directed design and free design game iterations collected by workshop

Directed Design	Free Design
Workshop 7	Workshop 9
Workshop 12	Workshop 13
Workshop 16	Workshop 17
Workshop 18	Workshop 19
Workshop 21	Workshop 22
Workshop 24	Workshop 26
Workshop 28	Workshop 30

As the participants worked on their games one of the challenges was ensuring that an equal level of difficulty was designed into both the directed design and free design games. To promote the transfer of the skills learned in the directed design to the free design games participants were provided with examples of games that showed best practices in each skill. Moreover, the participants played each other's games and gave feedback in terms of the levels for the programming, artwork, mechanics and narrative.

5.2 Quantitative Content Analysis

This research used a quantitative content analysis (Riff, Lacy & Fico, 2014) to examine how learners' problem solving abilities compared between the directed design and the free design games. A primary data source for this study was the learners' digital games and game design artefacts. The learners' directed and free design games were saved separately by sessions, so multiple iterations of the games at various stages of development were examined. The following data sources were collected and used in the interpretation of results: (1) learners' game design documents, (2) the learners' directed and free design games, and (3) director observations. Both authors were present for all sessions and worked collaboratively to code and analyse the data.

The cases represent the entire Project Tech group that completed 30 workshop sessions over the course of six months; workshops were 90 minutes long. The directed and free design games were completed on the same timeline and iterations of each game was saved during each workshop. For the purpose of this study, the authors define the directed design as the game every participant worked on and was scaffolded during each workshop. Free design games were created by the participants and were supported by request from the students. To obtain data for analysis the authors used 5 directed games each with 7 iterations (n=35) and 5 free design games with 7 iterations (n=35). Participants worked in the same groups for both the directed and free design games.

There were two obvious threats to validity of the game iterations data that the authors investigated and were able to overcome. First, since the game iterations are constructed from a set of learning outcomes, the authors were concerned the structure would elicit game designs that would be too narrow to use for the broad study discussed herein. After reviewing 20% of the game iterations from the directed and free design games, the authors concluded that the learning outcomes had not created games that all followed the same structure; in most instances by addressing the learning outcomes, the participants essentially told the story of how they understood the problem solving goals and what enablers and barriers there were to achieving those goals. Because game iterations were saved for the purpose of fulfilling Project Tech requirements, the second threat to validity was the potential for learner bias by the directors. The authors were able to set aside this concern for two reasons. First, if learner bias was present, the authors would expect it to be equal across both directed and free design. Second, the way the game iterations were evaluated limits learner bias. Each game iteration matches to a specific learning outcome and the directors made notes about each teams' progress as well. Additionally, the authors have access to all the game iterations and game artefacts which state what was completed by who and by what date. These factors suggest it would be fairly difficult for the game iterations or game artefacts to be tainted by learner bias to make it through Project Tech without being questioned by one of the directors.

5.3 Method of analysis

The iterations of the directed design and free design games and director notes relating to each iteration were content analysed with the assistance of statistics software program ATLAS/ti. The initial coding was done by the authors and was audited by a fellow researcher. None of the coders knew whether the game was directed or free designed during the coding. The iterations and notes were coded using standard content analysis techniques (Lincoln and Guba, 1985). The relative contributions of the iterations and director notes were taken into consideration in the initial stages of data analyses by triangulating all the data and benchmarking against prior studies. The minor discrepancies that existed between the coders were resolved by examining the data together.

The iterations and notes were initially coded at the design level by reviewing each iteration of artefacts line by line (e.g. code screens, storyboards, and daily notes) with each substantive line and game segment assigned to one of four categories. Consistent with the literature review on problem solving the categories were representing characteristics, planning characteristics, executing characteristics, and evaluating characteristics. The lines and segments were then analysed to identify variables, such as identifying problems accurately and modifying strategies. Examples of how the coding was done are provided in **Table 1**. Although categories identified in the literature review were used to guide the coding, the variables that emerged through the content analysis do not map perfectly with the variables that were identified. In these cases, either the variables identified in the literature review were not present in the game iterations, notes, or artefacts, or they did not contain enough fidelity for the content analysis to pick them up. In several cases, variables that we did not find in the literature review emerged from the content analysis and appeared important in the game design in our study. These variables are identified and discussed in the results section.

Table 1: Examples of the coding schema for problem solving skills.

Coding category	*Example*
Representation characteristics	
Distinguishes between static problems and dynamic problems	Bulling [sp] is all the time, not only in school (from initial storyboard on directed design)
Links to past experience	We pick up litter for school we could make a game about litter (from free design brainstorming)
Identifies problem accurately	More parts to bullying. Maybe we put in all people who are there. Bully, victtim [sp], teacher, friends, mom. (from notes on free design iteration)
Communicates problem in lay terms	Abuse is bad. We need to show how to stop abuse. (from notes on free design iteration)
Planning characteristics	
Searches for information	Find defnitiion [sp], look at websites, ask D (from notes on storyboard for directed design)
Creates a situational model	What if it was me, what would I do and who would I go to for help? (director notes of learner conversation about free design on peer pressure)
Demonstrates planning actions and other solution steps	1- players, 2- need title, 3- more action, 4- what about flying? (taken from notes on second iteration of free design game)
Executing characteristics	
Identifies goal first	Game is for kids and kids neeed [sp] clues for how toplay [sp] the game (from directed design notes on first iteration)
Follows logical progression	Maybe we should put numbers by what we do so we can do it on the other game (director notes of learner conversation about directed and free design)
Addresses interconnectivity if applicable	Like this, we need more info from here (crossed out line and put arrow to research from directed game to free design game notes)
Modifies strategies	[Partner name] can you do it this way if we switch these characters (director notes of learner conversation about free design)
Orders/integrates information	Story is the first thing, characters, actions. Put more work here for words (from free design notes on third iteration)

Evaluating characteristics	
Demonstrates criteria for evaluation	Does it work? After that all we need to know is who did it best. (from director notes of learner conversation about free design)
Proposes alternative solutions	Here we should do more action moves. Look? Sound? Moves? (from directed design notes on fourth iteration where learners considered the feedback from players)
Argues with evidence for specific solutions	This move worked in the last part but now it doesnnt[sp] work. Going back to the last version and testing the move again. (from directed design notes on third and fourth iteration)
Displays critical reflection	I learned that I can learn to do this and that there are ways to make the game work. I know the steps now and can jump around for my other game (from director notes of learner conversation about directed design)

In an effort to increase confidence in the reliability of the coding process used, four graduate students in games research coded randomly selected subset of 3 iterations of the directed and free design games code lines, game segments, and associated notes. A third coder, a research colleague not involved in the original coding process also coded these 6 random iterations to check for confirmation bias using the same process as the authors. The authors then compared the results of the two groups with the original coding data. Interrater agreement between these coding tasks was 87.42%. That is, of the 96 codes created (6 iterations times 16 variables), the two sets of raters agreed 84 times. Interrater reliability was also stable across the directed and free design games: 92.7% (89/96) for directed design and 90.6% (87/96) for free design games.

6. Findings

Table 2 presents the categories and variables that emerged from the study. Throughout the analysis, the authors were interested in the extent to which the participants demonstrated these variables. The frequency of emphasis for each variable, broken down by directed versus free design, is shown in the table. The authors chose this method of frequency analysis to ensure that vivid, but false impressions (Holsti, 1969) were not regarded as more meaningful and pervasive than otherwise might be inferred with such frequencies.

A two-tailed, Fisher's Exact Test was used to test the differences between frequencies for the directed design and the free design games. The Fisher Exact Test was used as one or more of the cells had an expected frequency of five or less and the chi-square test was not appropriate (Raymond & Rousset, 1995; Upton, 1992). As shown in Table 2, the problem solving characteristics in the directed design differed from the free design games with regard to intensity of emphasis on 7 of the 16 variables identified. In general, the variables that emerged from the study are consistent with the variables identified through the literature review, with several important exceptions. Through the content analysis, several variables emerged that are not prevalent in the existing literature on problem solving and higher order skills with special needs students; these were emphasized to a significantly higher degree by the free design iterations as opposed to the directed design in the study. These variables include communicating problem in lay terms, searching for information, and arguing with evidence for specific solutions.

Overall the free design games encouraged the special needs young people to work on problems that were important to them while the directed design games were assigned and based on scaffolding the learning process. Moreover, the free design games emphasized the role of the game designer as the content expert, requiring the participants to seek out and find information rather than it being supplied during the directed design. Finally, both the free design games and the directed design games promoted evaluating work in progress over completion, however the participants were more invested in the successful completion of the free design game and worked hard to support their design solutions with evidence.

Table 2. Variables identified in content analysis with Fisher's Exact Test for significance across design activities with special needs young people.

Number of iterations affected out of the total (n=35 for directed and n=35 for free design)			
Variable	Directed design iterations	Free design iterations	*P* (Fisher's Exact Test)
Representation characteristics			
Distinguishes between static problems and dynamic problems	17	23	.2270
Links to past experience	21	19	.8094
Identifies problem accurately	15	12	.6238
Communicates problem in lay terms	20	32	.0021**
Planning characteristics			
Searches for information	22	34	.0006***
Creates a situational model	13	27	.0015**
Demonstrates planning actions and other solution steps	30	24	.1535
Executing characteristics			

Identifies goal first	26	29	.5613
Follows logical progression	8	12	.4279
Addresses interconnectivity if applicable	14	4	.0125**
Modifies strategies	11	19	.0902*
Orders/integrates information	10	3	.0624*
Evaluating characteristics			
Demonstrates criteria for evaluation	4	7	.5130
Proposes alternative solutions	11	14	.6183
Argues with evidence for specific solutions	2	15	.0005***
Displays critical reflection	3	3	1.000

*P<.10
**P<.05
***P<.01

6.1 Representation characteristics

The free design differed from the directed design on communicating problems in lay terms, a variable that is relatively unexplored in prior research with special needs young people and problem solving (Atadokht, Norozi & Ghaffari, 2014; Kolodner, et. al, 2003; Yssledyke, 2005; Zheng, Flynn & Swanson, 2013). This variable was assigned when an iteration contained notes in the code about making the problem more explicit in the game or when dialogue appeared on defining the problem within the gameplay. The inclusion of either of these forms of information, which were significantly more prevalent in the free design games versus the directed design games, suggests that the free design games emphasized the responsibility of the team to the game player on being as clear as possible in the gameplay. The insight is supported by director observations of team meetings where participants spent a large percentage of their design time perfecting the language of the game. Iterations of the free design games had substantially more changes to the dialogue and directions of game from iteration to iteration than the directed design games. This demonstrates that coherence and clarity of the game problem and how to design it clearly was a major concern for the free design games over the directed design games.

The study affirmed the importance of linking to past experiences and identifying problems accurately in design activities with special needs young people (Krawec, 2013). Moreover, the lack of significant difference between directed design and free design game iterations demonstrates that representation characteristics in problem solving activities need to be heavily scaffolded with special needs young people (Hwang, Kuo, Chen & Ho, 2014). By linking past experiences to current game design activities in both the directed and free design iterations participants were able to create a narrative about their role in the social issue being discussed. For example, the directed design activity focused on peer pressure and each of participants was able to draw on prior experience about the impact of peer pressure on actions.

6.2 Planning characteristics

The free design iterations in the study differ from the directed design iterations on searching for information and creating situational models. No differences between the two groups were found in the emphasis on demonstrating planning action and other solution steps. With regards to searching for information, whereas researchers have found that scaffolding such activities creates greater accuracy in problem solving participants rarely learn the skills to do their own information searches without some form of support in special education (Bulgren, Sampon Graner, & Deshler, 2013). This may be due to their relative inexperience and lack of confidence with the subject material. As a result, the free design iterations show a greater intensity to "search for information" because the participants chose topics with which they were familiar.

The free design iterations significantly emphasized the creation of situational models over the directed design iterations (*P*<.0015). Research has demonstrated that using contextual clues () and considering stakeholders (Basham & Marino, 2013) as important steps in planning. The significant emphasis by free design iterations may be due to the experiences of the participants and their increasing confidence with game design. As a result, the participants demonstrated greater planning characteristics as these games were owned by the participants more than the directed design games.

While not significantly emphasized to a higher degree the demonstrates planning actions and other solution steps was an interesting finding in its lack of statistical difference (*P*<.1535). All participants were urged to demonstrate their planning actions during the game design, both directed and free design. It was evident from the iterations that keeping the planning actions as a guide was promoted, virtual sticky notes were attached to each iteration that listed key steps for the projects.

6.3 Executing characteristics

The free design iterations in the study differed from the directed design iterations with regard to addressing interconnectivity, modifying strategies, and ordering/integrating the information. The directed design iterations demonstrated significantly more instances of addressing interconnectivity and ordering/integrating information than the free design iterations. One explanation for the significant emphasis on the directed design iterations for these attributes is teamwork. All work was done in teams and while executing the game design, both directed and free, yet the process of actually programming had to be done by one person while the other sat beside them and directed the programming. The ability to interconnect between the planned execution and actually execution involved addressing bugs as they appeared on the screen. This is a form of social constructivism (Kafai & Burke, 2015) and the directed design enabled the participants to execute their problem solving prior to ordering and integrating information. Participants were then able to use those skills on the free design without creating extra work within the executing steps, thus they were not visible during the coding.

Modifying strategies differed significantly from free design to directed design iterations. This may be due to free design iterations creating more opportunities for participants to problem solve their own ways rather than being on a directed path. The most compelling example of this is in the coding for game mechanics during the final level of each game where multiple examples of modifications are seen throughout the iterations compared to the directed design.

6.4 Evaluating characteristics

The final category of variables examined in the study was evaluating characteristics. Of the four characteristics only argues with evidence for specific solutions differed significantly from the free design to the directed design iterations. No differences were found in demonstrates criteria for evaluation, proposes alternative solutions, and displays critical reflection.

Arguing with evidence for specific solutions has received coverage in the problem solving literature (Reid, Lienemann & Hagaman, 2013; Ysseldyke, 2005), but the incidence of argumentation in the free design over the directed design was higher. In most cases, the free design iterations were evaluated more closely by the game design participants than the directed design iterations. This may be due to a sense of ownership over the free design that did not exist in the directed design. The free design iterations in the study also emphasized the power of free choice while deciding on success and what that constituted for problem solving during game design. It was apparent that the free design iterations had more effort put into the games in terms of evaluation and how the game design participants could voice their solutions with support.

While not significantly emphasized to a higher degree the displays critical reflection attribute was an interesting finding in is lack of statistical difference (P<1.000). This was the most difficult attribute to find evidence of in both the directed and free design iterations. Recent research has discussed the difficulties in measuring critical reflection in special needs students (Cortiella & Horowitz, 2014; Lundberg & Reichenberg, 2013) and in evaluation in general in game design (Mitgutsch & Alvarado, 2012). Specific examples of critical reflection in the iterations was explicit in terms of the phrasing in the code; “We reflect here that the movement of the boss has to be more lined up with the players moves” and “This is crap. The player walks through the wall no matter what we do. Next step is recoding this part” (quotes taken directly from the directed design games).

7. Summary

Most of the findings reported above affirm the existing literature on problem solving and special needs young people. The characteristics of representation, planning, executing, and evaluating in problem solving, are important in helping a special needs young person design a game based on a social issue of their choice. The results of the study are important because they confirm the results obtained through conventional deductive research, which is represented by the majority of studies cited in the literature review.

Two new concepts emerged from the content analysis that had not been considered in the literature. First, the variable "creating situational models" in the planning characteristics was identified, based on the evidence in the game iterations that some problems required more modelling than others in terms of design and coding. These instances can create a greater valence for success with certain game design groups, which might spur them onto a trajectory of good game design within the free design iterations. Some iterations may simply require more situational modelling than others to create a workable plan for the young people, which is a notion that is hard to quantify but may nonetheless exist.

Second, in the category executing characteristics, the variable "addressing interconnectivity" emerged as a strong indicator that the directed design was better for execution in problem solving. Although this variable is conceptually similar to social constructivism (Kafai, 1996) the results of this study suggest that addressing interconnectivity is a separate concept and refers to the ability of special needs young people to work within the constraints of the design to see connections and recognize the steps they need to take to create links between like problems rather than reconstructing the same steps for every coding issue.

Finally, the results of this study draw attention to the importance of problem solving practices in facilitating a shift from directed to free game design not considered in the area of special needs education or problem solving literature emerged from the content analysis. First, the emphasis on "explains problems in lay terms" was found to be much more prevalent in the free design as it was demonstrated in 91% of the free design iterations compared to 57% of the directed design. Second, a clear distinction emerged from the content analysis in the "argues with evidence for specific solutions" within directed and free design iterations and notes. Whereas the use of demonstrating evaluative criteria and proposing alternative solutions was similar in directed and free design iterations, the latter were much more likely to demonstrate use of argumentation for specific solutions.

7.1 Limitations

This exploratory study has two major limitations and one minor limitation which make the validity of the findings rather limited. The first is the sample size (n=11) of special needs young people who participated in the study. One of the ways we chose to negate some of the concerns about the small sample size was to use the Fisher Exact test to explore distinctions between the directed design and free design games as it is considered a non-parametric test; it does not make assumptions about distribution of the population or that the measure derives from an equal-interval scale (Gibbons & Chakraborti, 2011). Second, the study was conducted during the school day and while the special needs young people were given the option of participating the alternative was to do their normal school work. This left us with a rather captive population. We would like to note that one student did choose school work over the study. A minor limitation of this study is that all participants contributed both a directed design game and a free design game. Comparisons between the games would not work as one was heavily scaffolded and one was not, plus the free design happened after the participants had worked on the directed design game. This was an intentional design decision on our part though, and the study does not compare the sophistication of the game design but rather the problem solving skills that are demonstrated through each design.

8. Implications, observations, and conclusions

The results of this paper provide several important implications for problem solving in game design with special needs young people to advance our understanding of how the attributes identified impact current scholarship. First, problem solving is not a random event. A special needs young person representation, planning, executing, and evaluating characteristics make a difference in terms of their ability to free design games around social issues. The problem solving variables most supported by free design in this study are shown in Table 2. Schools and programmes who use game design with special needs young people may benefit from studying this table and considering the extent to which their institutions embrace the variables identified during problem solving exercises. For example, one of the strongest findings in the study is that when special needs young people participate in free design they "argue with evidence for specific solutions" to solve their game design problems. This is a finding that a programme could implement at no cost and scaffold through directed design activities to be a learning outcome. Promoting using specific solutions to solve problems creates the expectation within the programme that young people will be leading their own design and demonstrate that ownership through knowledge and expertise.

A second implication of the study is that the personal characteristics of the participants and directors who work on the game design iterations together have an impact on the problem solving contents applicability in the free design. The most important variables in this area are communicates problems in lay terms, searches for information, and modifies strategies. It may benefit new programmes to pay attention to these variables, and include training for programme directors on these specifics to promote these characteristics with their special needs young people.

To conclude the paper, the authors would like to make two observations about the results of the present study, designing games with special needs young people, and the present state of academic literature on problem solving in project based learning.

First, none of the categories of variables examined in the study are holistic, they each study problem solving from a narrow point of view. For instance, the literature on problem solving focuses on the attributes that potentially provide one type of learner an advantage over another in identifying problem solving steps and ability to solve problems. Although it is tempting to criticize the literature for organizing itself into neat categories, without much integration across categories, it is impressive that these four categories provide concrete advice to programme leaders and institutions where problem solving through game design are used with special needs young people. In addition, each category, as shown in the literature review, contains variables that have been shown to facilitate problem solving skills across different settings. As a result, the authors thinking evolved during the course of the study and became even more impressed with the breadth and depth of the literature on problem solving and game design with young people than at the outset. As a result, the authors believe the results of the study will add to the rich literature that is slowly populating problem solving and game design with young people in special needs classrooms.

The second observation is that although the literature on problem solving and game design with young people has some links it does not converge and there is a need for more integration across the categories of variables that are associated with special needs education. For example, where the literature on problem solving does much to explain higher order thinking in mainstream students, the literature on problem solving rarely cites special needs in explaining practices. As a result, stand-alone statements that emerge from a single category of variables such as "modifies strategies" are not very helpful. Most educators are aware of the importance of modifying strategies. The challenge is in determining how to acknowledge the role of strategies in problem solving with special needs students and their process for modifying those strategies. In the context of game design, this may mean the partnering of special needs teachers with game designers, creating specific steps for strategic planning in the programme, or a host of other alternatives. The cross-integration of topics, like young people and game design, will move the literature on problem solving with special needs populations forward and will enrich the field. The point is that programme leaders, institutions, teachers, students and carers should be equipped with the background necessary to identify the way that game design and problem solving can inform the success or failure of a game design intervention. The authors hope this study contributes to that dialog.

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