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How digital scaffolds in games direct problem-solving behaviors

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ABSTRACT

Digital systems offer computational power and instant feedback. Game designers are using these features to create scaffolding tools to reduce player frustration. However, researchers are finding some unexpected effects of scaffolding on strategy development and problem-solving behaviors. We used a digital Sudoku game named *Professor Sudoku* to classify built-in critical features, frustration control and demonstration scaffolds, and to investigate their effects on player/learner behaviors. Our data indicate that scaffolding support increased the level at which puzzles could be solved, and decreased frustration resulting from excessive numbers of retries. However, it also reduced the number of unassisted placements (i.e., independently filled cells), and increased reliance on scaffolding tools, both of which are considered disadvantageous for learning. Among the three scaffold types, frustration control reduced the potential for players to feel stuck at certain levels, but also reduced the frequency of use of critical feature-making tools, which are thought to have greater heuristic value. We conclude that the simultaneous provision of critical feature and frustration control scaffolds may increase player reliance on available support, thereby reducing learning opportunities. Providing players with critical features and demonstration scaffolds at the same time increases reliance on available support for some players, but for most it encourages the development of solving strategies.

1. Introduction

Learning environments that make use of digital games can be leveraged to incite learner motivation, increase focus, and disperse learning effects (Barab, Thoma, Dodge, Carteaux, & Tuzun, 2005; Gee, 2003; Prensky, 2001). Rosas et al. (2003) surveyed research on applying digital games as instructional tools, and identified four dimensions of learning that games can support and strengthen: school achievement, cognitive abilities, learning motivation, and attention and concentration. According to a large-scale game-based instruction experiment in Great Britain, the general conclusion among most teachers and parents is that games can contribute to strategic thinking, communication planning, number application, negotiating, group decision-making, and data-handling skills (Kirriemuir & McFarlane, 2004). Other researchers have reported that games can create environments that promote active participation in problem solving (Garris, Ahlers, & Driskell, 2002) and meaningful learning (Kiili, 2005). According to Gredler (2003), learners who use educational games or simulations are required or encouraged to apply knowledge, skills, and strategies for executing their assigned roles and gaining the full benefits of experiential learning. Gee (2003) uses the term “learning machines” to describe games that do a good job of supporting learning mechanisms. Games in all formats can guide players through the process of discovering more advanced rules for problem solving. Digital games can offer challenging problems and provide opportunities for routinizing and automatizing solutions. For example, games that pit players against computers can help children develop mathematical reasoning skills by learning strategies that are modeled by machines (Houssart & Sams, 2008).

1.1. Digital scaffolds

Wood, Bruner and Ross’s (1976) scaffolding concept is based on the learning theories of Vygotsky (1962), who is credited with the idea of a *zone of proximal development* (ZPD) that exists between learner ability to solve a problem alone, and the ability to solve it with assistance or

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guidance. Wood et al. (1976) described a learning process in which instructors provide temporary support to help students develop initial learning skills, and then gradually reduce support as students improve on their own. The temporary support (e.g., a scaffold) can come in the form of an instructional strategy or tool. In a ZPD, the learning process gradually evolves from interaction to internalization—a type of "responsibility transfer." The overall goal is to help students get a better grasp of their own knowledge construction.

While scaffolds used to be provided by teachers or peer learners, they can now be programmed into computer software and digital games. Researchers who have analyzed the use of computers for assisted learning scaffolding include Davis and Miyake (2004), Demetriadis, Papadopoulos, Stamelos, and Fischer (2008), Hmelo and Day (1999), Yelland and Masters (2007), and Zydney (2010). Salen and Zimmerman (2004) describe the instant feedback, computation power, graphical representation, and interactivity of digital environments as positive characteristics in terms of player data collection and rule induction. They believe that players who are given sufficient support and guidance are less likely to become frustrated by repeated failures, or to give up under excessive cognitive loads. Fisch (2005) suggests that sufficient scaffolding can help players refine their strategies, resulting in greater learning effectiveness.

Many support tools found in digital games were not specifically designed for learning purposes, and therefore cannot be analyzed as learning scaffolds. According to Bos (2001), digital game designers are skilled at utilizing scaffolding theory, but their focus is on preventing frustration instead of providing support for learning. Thus, their scaffolding approaches have the potential to act as learning barriers. Since they have a strong interest in making sure that players do not become too frustrated and give up, game designers are adept at devising supportive tools for overcoming bottlenecks (Davis & Miyake, 2004). Educational goals are different, yet some scholars suggest that scaffolds can help students attain a higher level of learning in self-regulated contexts (Hannafin, Land, & Oliver, 1999; Jackson, Stratford, Krajcik, & Soloway, 1994). Our goal in this study is to determine whether a scaffolding support structure in one digital game is capable of either actively increasing learning effectiveness, or passively decreasing the potential for frustration.

From the perspective of constructive learning, scaffold type and the timing of scaffold presentation and/or removal are equally important. The list of scaffold types includes recruitment, reduction of degree of freedom, direction maintenance, critical feature marking, frustration control, and demonstration (Wood et al., 1976). Kintsch (1991) emphasizes that computer learning environments should offer "temporary support" to help learners perform tasks beyond their capacities, rather than simply give intelligence for the purpose of directing or monitoring learning progress. According to Vygotsky (1978), scaffolds can help learners transcend the gap between prior knowledge and current goals, but as familiarity with learning material increases, scaffolds should be removed. Furthermore, since learners are capable of independently acquiring new knowledge and skills without having to rely on instructional assistance (Greenfield, 1984), it is important to avoid providing scaffolds too early or noticeably. This is especially true for educational environments, but less so for recreational gaming.

1.2. Sudoku

For this project, we used *Professor Sudoku* (a digital version of the popular Sudoku game) to investigate the effects of built-in scaffolding on gaming and learning behaviors. Sudoku has been described as helping players develop logical reasoning skills (Baek, Kim, Yun, & Cheong, 2008; Mepham, 2005). A typical Sudoku game has 9 grids of 3 x 3 cells, with some cells already filled in with numbers. An example of a Sudoku puzzle is shown in Fig. 1. The game objective is to fill in the rest of the empty cells with numbers from 1 through 9, with each digit appearing only once in each row, column, and grid. Sudoku rules are clear and simple. The digital version does not require complex computing skills, but does require the ability to reason and to think logically. Players must use a divergent thinking approach to identify possible solutions, and a convergent thinking approach to select the best one. This explains why *Teacher Magazine*, published by the UK government, believes that Sudoku should be introduced into classrooms (Holden, 2005).

Solving strategies are also taken into consideration by digital and non-digital game designers in terms of checkpoints and support tools. A solving strategy is defined as a plan for problem-solving actions derived through mental effort to change the status of a problem. The list of general solving strategies includes generate-and-test, means-end analysis, analogical reasoning, and brainstorming, among others (Schunk, 1996). Depending on the strategy in question, scaffolds can either provide guidance or increase reliance. Using Sudoku puzzles as an example, most players (especially newbies) initially apply a direct elimination technique, filling in numbers in ways that do not violate the rules. Players who proceed from one level to the next have the potential to develop higher-order puzzle-solving skills.

1.3. Study purpose

We had two goals in mind when designing this study: identifying scaffold types that players can actually benefit from, and exploring their effects on solving strategy development and learning. By manipulating combinations of *Professor Sudoku* scaffolds, we observed which scaffolds were best in terms of preventing frustration, and tried to determine whether such temporary support is capable of inducing self-

Fig. 1. Example of a Sudoku puzzle.

learning and supporting strategy development. Since games represent a kind of activity in which process is more important than result, we focused on identifying actual or potential links between gaming behavior variation and scaffold type. In summary, our intent was to analyze the effects of different scaffolds on player gaming behaviors, strategy changes according to different scaffolds, and usage differences and interactive effects associated with different scaffold types.

2. Research design

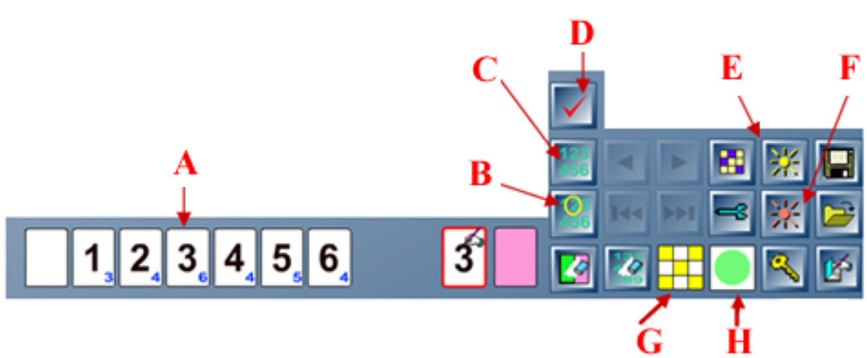
Many free Sudoku programs are available on the Internet. We selected *Professor Sudoku* because it has a digital interface that clearly presents visual support (including "contrast grid" and "highlight specific number" features), and shows the availability of problem-solving tools ("check errors," "show number of cells left for each number," "generate candidates," "show possible cells," "show hints for the next step" and "show detailed hints for the next step") (Fig. 2).

Professor Sudoku contains the three types of scaffolds mentioned by Wood et al. (1976): critical feature marking, frustration control, and demonstration. Critical feature-marking refers to the use of various methods to encourage learners to pay attention to certain objects or goal features. *Professor Sudoku* has three tools of this type: the automatic display of the number of remaining cells requiring digits, the highlighting of all cells already filled in, and the use of two colors to display the nine 3 x 3 grids (Fig. 3a). We did not test the individual effects of the critical feature-marking scaffold because it does not directly influence problem-solving processes. Instead, we joined it with the other two scaffold types to observe their effects in combination.

Professor Sudoku also contains four frustration control tools (Fig. 3b): one that marks cells containing incorrect digits with a different color, one that shows all possible candidates for each empty cell, one that shows possible cells for a specific digit, and one that shows which cell should be filled in next, and which digit to fill it with. Finally, the game has a demonstration tool that is meant to provide clear guidance. By using the "show detailed hints on the next step" function (Fig. 3c), players can learn why they should follow suggested steps, which helps them induce game rules and develop their own strategies.

From the most simple to the most complex, primary Sudoku solving strategies are single candidate, basic elimination, block elimination, naked single, X-Wing, and unit elimination (Davis, 2010). To match the level of our study participants (elementary school students), we collapsed some of the above-mentioned strategies into two categories: single candidate and single position. The single candidate technique consists of searching for forced cells—that is, cells in which only one digit is possible. When 8 of 9 cells in a row, column, or grid have been filled in, the remaining cell is considered a forced cell. The single position technique consists of finding the only possible cell for a specific digit, based on the principle that each digit between 1 and 9 can only appear once in each row, column, and grid. We observed that in most cases, the single position technique was the first one used after the single candidate technique. Using the puzzle in Fig. 4 as an example, since the cells located at positions (4, 1), (7, 2), (8, 8) and (9, 4) all contain the digit 2, that digit cannot appear a second time in rows 4, 7, 8 or 9. Since the digit 2 is missing from column 9, cell position (6, 9) is the only possible cell in which 2 can be inserted.

We divided our participants into three groups: frustration control, demonstration, and no scaffold. Regarding gaming behaviors, we observed three main variables: (a) clear-all times, meaning the number of times a player cleared all numbers in order to start a new puzzle; (b) number of unassisted placements, meaning the number of cells filled in without the use of scaffolding tools, indicating that a player has grasped certain rules or problem-solving strategies; and (c) bogged-down times, representing the number of times a player filled in all empty cells but still could not solve a puzzle, indicating lack of self-knowledge of a wrong solving path until all empty cells have been filled.



A: show number of cells left for each number
B: show possible cells
C: generate candidates
D: check errors
E: show hints on the next step
F: show detailed hints on the next step
G: contrast grids
H: highlight specific numbers

Fig. 2. Support tool interface in Professor Sudoku.

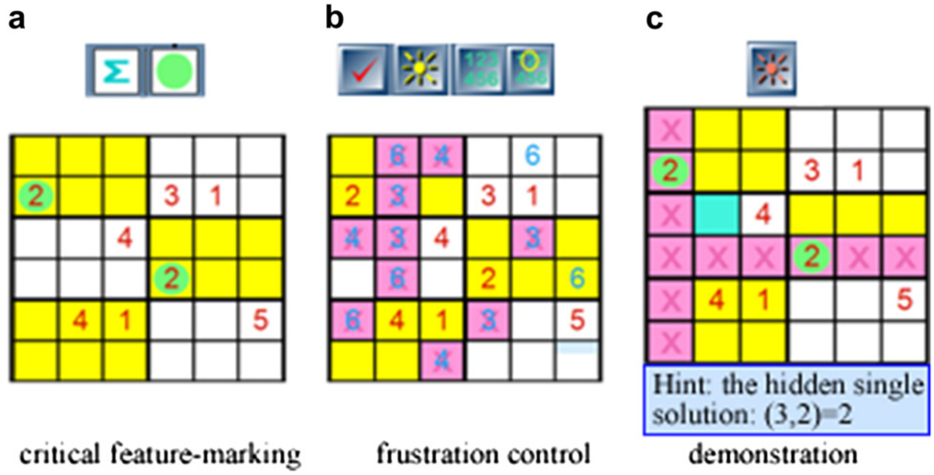


Fig. 3. The three Professor Sudoku scaffold types.

As stated above, the critical feature scaffold does not offer solution hints, but it does visually present game statistics to help players discover latent rules or develop creative solving strategies. Since it has the potential to exert a positive effect on player learning, we interpreted increased or decreased usage of this scaffold type as an indicator of independent thinking.

In summary, we offered different combinations of scaffolds to *Professor Sudoku* players in an attempt to induce logical reasoning, as well as to support ZPD and higher-order thinking techniques. We also established a no-scaffolding control group to investigate the effects of scaffolding support on gaming and solving behaviors, and analyzed differences in usage and interactive effects among various scaffolds. Our study design is illustrated in Fig. 5. Our main hypothesis is that demonstration scaffolds create fewer disturbances to player learning, and that frustration control scaffolds tend to increase player reliance on available support, thereby exerting a negative effect on learning.

3. Pilot study

In March, 2010 we conducted a pilot study with twelve fifth-grade students attending a school in northern Taiwan. For this part of our project we used the 6 x 6-cell version of *Professor Sudoku*, based on our perception of the skill level of fifth-grade students. All participants were given a five-minute introduction to Sudoku rules and playing methods, and then allowed to play the game for 20 min. A follow-up test was conducted the following month, with the same 12 students given access to different scaffolds and asked to work on puzzles for 60 min. Gaming behaviors during both test sessions were recorded using screen capture software. This allowed us to observe the most commonly used solving strategies, and to present scaffolding tools in the most efficient manner when designing the user interface for our main experiment.

We identified four levels of problem-solving behavior: high, mid, low, and zero. High-level refers to the consistent application of elimination techniques, which requires a systematic approach involving logical reasoning. Mid-level refers to the hidden technique of determining which cell, column, or grid should be solved first. Low-level solving behaviors include guessing or a trial-and-error approach to solving specific cells or grids. Zero-level indicates complete reliance on scaffolding tools to solve puzzles.

Using pilot study results, we asked Mr. Kuang-Chen Wu, the *Professor Sudoku* programmer, to develop three different versions of his game: one with mixed critical features and frustration control scaffolds, one with mixed critical features and demonstration scaffolds, and one with no scaffolds at all. The program was designed so that it would neither automatically provide hints nor give warnings when a player was about to make a mistake. During the main experiment, all players dealt with the same number of empty cells and difficulty levels. The average number of steps required to solve a puzzle was 35.

Fig. 4. An example of “single position” technique.

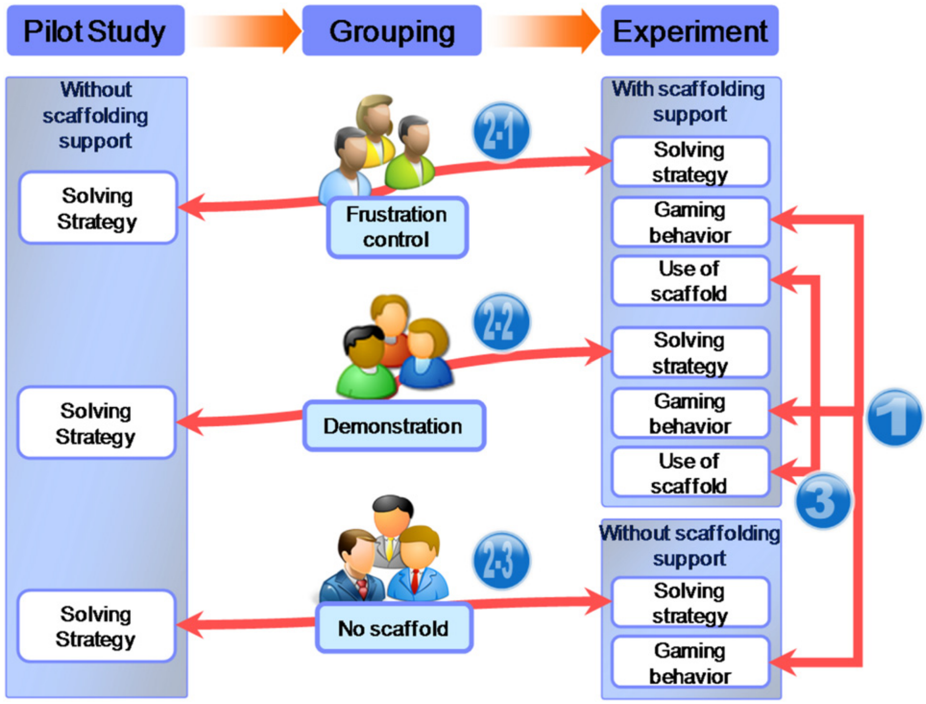


Fig. 5. Study design.

4. Analysis

We recruited 213 students from 7 sixth-grade classes in an elementary school located in Hsinchu City, Taiwan. They were initially asked to play *Professor Sudoku* without scaffolds for 20 min. Based on results from these games, we selected 90 students whose gaming behaviors and strategies were similar to those observed in the pilot study students, and randomly divided them into three groups. We made every possible effort to maintain equal percentages of girls and boys in each group. Acknowledging that experimental results might be affected if students attempted to practice Sudoku skills on their own between the sampling period and formal experiment, we observed solving behaviors during the first three minutes of each data collection period. Students who made significant and obvious changes in strategy were removed from the sample. The final sample consisted of 18 students in the frustration control group, 23 in the demonstration group, and 23 in the no-scaffold group.

4.1. Effects of digital scaffolds on game behaviors

Our first task was to analyze the general effects of the digital scaffolds on players, including numbers of solved puzzles at various levels, bogged-down times, unassisted placements, and retries. The data in Table 1 indicate that both scaffold combinations increased the numbers of solved puzzles and retry times, and decreased numbers of unassisted placements and bogged-down times—in all cases at statistically significant levels. No significant differences were found for the effects of the two combinations. In short, the supportive tools in *Professor Sudoku* mitigated frustration caused by game bottlenecks, and increased the chances of player success.

The number of retry times at each level varied significantly across the three groups (Table 1). Students in the no-scaffold group showed more retry times than those in the frustration control or demonstration groups, and students in the demonstration group had more retry times than those in the frustration control group. One possible explanation is that the error-checking tool let players in the frustration control group immediately discover mistakes and correct their digit placements, and therefore they did not need to experiment with or reinsert numbers multiple times.

Table 1
Effects of different scaffold combinations on game behaviors.

Variable	(1) Frustration control ($N = 18$)		(2) Demonstration ($N = 23$)		(3) No scaffold ($N = 23$)		ANOVA	Post hoc
	M	SD	*M*	SD	*M*	SD	$F(2, 61)$	
Total levels solved.	12.06	6.83	11.96	13.38	1.52	.84	10.389***	3 < 1, 2
Number of unassisted placements at each level.	52.57	35.67	59.64	62.07	173.75	94.37	20.478***	1, 2 < 3
Bogged-down times at each level.	.17	.26	.65	.61	1.38	1.51	7.994**	1 < 2, 3
Retry times at each level.	.01	.02	.18	.26	2.51	3.39	10.008***	1 < 2 < 3

**$p < .01$, ***$p < .001$.

Table 2
Chi-square test results for changes in solving behaviors before and after scaffold support.

Group	N	Comparison of strategy level with support and original strategy level			Significance (two-tailed)
		Negative (a)	Positive (b)	Equal (c)	
Frustration control	18	18	0	0	.000***
Demonstration	23	12	6	5	.238
No scaffold	23	0	3	20	.250

***$p < .001$. (a) Solving behavior level with support is lower than original solving behavior level; (b) solving behavior level with support is higher than original solving behavior level; (c) solving behavior level with support is equal to original solving behavior level.

4.2. Scaffold usage/solving strategy correlations

To determine variation in solving behaviors due to scaffold availability and type, we classified solving strategies according to the four levels described above. We awarded 4 points to high-level behaviors, 3 to mid-level, 2 to low-level, and 1 to behaviors that lacked any strategy. We compared the solving behaviors of each student before and after any instance of scaffold use, and then conducted chi-square tests to determine change significance. As shown in Table 2, no significant changes in solving strategy were found for students in the no-scaffold group, but a statistically significant decline was found for students in the frustration control group ($\chi2 = .000$, $p < .001$). Most of the frustration control group strategies were low-level and relied heavily on scaffolding support, suggesting that frustration control increases player reliance on scaffolding, and triggers a consequent decline in strategy development.

To better understand behavioral tendencies given support for frustration control, we analyzed the scaffold-added solving behaviors of students in this group. As shown in Table 3, the ratio of students making use of error checks, hints, and both tools combined was 12:1:4. Chi-square test results indicate significant differences among all three categories ($\chi2 = 11.412$, $p < .01$). When given access to the combined support of critical feature-marking and frustration control scaffolds, players tended to rely on the error check tool. Obviously, excessive reliance on this tool would not support the development of solving strategies.

As shown in Table 2, no statistically significant differences were found among players in the demonstration group in terms of solving behaviors given scaffold support. The demonstration scaffold may have exerted both positive and negative effects on solving behaviors, with the positive effects being offset by the negative. To determine the helpfulness of the demonstration scaffold for strategy development, we combined the results for low-level and no-strategy students and conducted a second significance of change test. Those results indicate statistical significance ($\chi2 = .031$, $p = <.05$), suggesting a positive effect of the demonstration scaffold on player strategy development (Table 4). We also noticed a strong tendency among some players to use “detailed hints on the next step,” which can also be viewed as reliance on scaffolding support.

4.3. Differences in usage and interactive effects among different types of digital scaffolds

To determine whether players in the two scaffold-support groups used tools at different frequencies, we compared the use of the critical feature-making tool between the frustration control and demonstration groups. As stated, these tools offer visual and statistical support, but exert no direct influence on the development of solving strategies. Still, they can exert a positive influence on player learning by supporting the induction of latent game rules and the development of creative solving strategies. Learning may be affected if critical feature-making tool usage decreases due to the availability of other tools. Our data indicate that the students in the frustration control and demonstration groups used critical feature-making tools .85 and 3.57 times on average per level during a 40-min game session (Table 5). ANOVA test results indicate a significant between-group difference ($F = 4.520$, $p < .05$). We observed that players seldom used the critical feature-making tools when they had access to frustration control tools. In comparison, demonstration tool group players were much more likely to use the critical feature-making tools, indicating that the frustration control group players were confident that they could solve puzzles using only the frustration control tools—further evidence that reliance on supportive tools diminishes learning opportunities.

5. Discussion

Our results indicate that learners who have scaffolding support are more able to solve game puzzles, which supports Ma, Williams, Prejean and Richard’s (2007) suggestion that educational game developers add different types of scaffolding to their designs. According to Kiili (2005), prior learner knowledge and experience affect game world experiences and perceptions. When game challenges significantly exceed player skill level, anxiety arises. Game system guidance or help from other learners increases the potential for achieving the state that Csikszentmihalyi (1975) described as *flow*. However, educational goals that are more important include knowledge development and internalization—that is, improved potential for learners to achieve success after scaffolds are removed. Our results indicate varied effects of scaffolding on learning.

Table 3
Goodness-of-fit test results for student solving behaviors with frustration control support.

Solving Behavior	Observed *N*	Expected *N*	Residual	χ^2
Error check.	12	5.7	6.3	11.412**
Hint.	1	5.7	−4.7	
Error check plus hint.	4	5.7	−1.7	

**$p < .01$.

Table 4
Chi-square test results for change in solving behaviors with demonstration scaffold support.

		N	Significance (two-tailed)
Comparison of strategy level with support and original strategy level.	(a) Negative	0	.031*
	(b) Positive	6	
	(c) Equal	17	
	Total	23	

*$p < .05$. (a) Solving behavior level with support is lower than original solving behavior level; (b) solving behavior level with support is higher than original solving behavior level; (c) solving behavior level with support is equal to original solving behavior level.

Table 5
ANOVA results for frequency of use of critical feature-marking tools between the two groups.

Group	*N*	*M*	SD	Analysis of Variance				
				Source	df	SS	MS	F
Frustration control group	18	.84	1.310	Between group	1	74.745	74.745	4.520*
Demonstration group	23	3.57	5.290	Within group	39	644.899	16.536	

*$p < .05$.

Participants who used the frustration control tools in *Professor Sudoku* were able to complete puzzles at higher game levels by monitoring the degrees of correctness of their current paths and associated potential for success. Fast feedback discouraged players from spending too much time on wrong paths, but also reduced the potential for inducing rules via trial-and-error learning, which should not be avoided simply because it increases the potential for frustration. Prensky (2001) has discussed this issue in terms of “failure tolerance,” which is a major feature of game worlds. During our experiment, we observed that students in the frustration control group relied heavily on the error check tool—in other words, they were reluctant to accept any risk of failure. Their overreliance on system prompts blocked them from internalizing knowledge acquired from interaction with the game system. Students in this group also did not use available critical feature-marking tools to develop problem-solving strategies.

Other scaffolds, such as the demonstration scaffold in *Professor Sudoku*, offer hints or suggestions for guiding players through a process of “finding the correct solution.” It is clear how easily this type of scaffold can undermine learning if overused, but most players acknowledge that overreliance on these tools can make a game boring and success meaningless. Striking a balance between the two must be a central goal of educational game design efforts. The more that students view an educational game as entertaining, the more they will control their use of scaffolds in order to maintain a sense of playfulness.

Scaffolds such as the critical feature-making tool in *Professor Sudoku* systematically present visualized game statistics. This can be very helpful for reducing cognitive load. As digital games become increasingly complex, it is hard for players/learners to understand all aspects of a game or to find correct solution paths entirely on their own; therefore, there is little need to discourage the use of this type of scaffolding tool. When games are specifically created for instructional purposes, designers may be interested in adding a function through which instructors can adjust informational scaffold type and content.

We also observed that even though students in the frustration control group consistently used the error check tool, they did not use the tool that gives detailed hints about the next step. Squire (2006) and other game researchers stress that in addition to game content, gaming behavior observations should focus on game situations and social contexts. We believe this also applies to supportive game tool research. Players may perceive problem-solving scaffolds in the same manner that they view dictionaries or calculators for use in tests. Motivation is clearly an important factor in how they use scaffolding tools; in some games they may be perceived as reducing a sense of fairness. However, as Consalvo (2007) points out, most players primarily use scaffolds to reduce frustration caused by being stuck, and avoid using them unless they feel seriously frustrated by multiple failures. A game player looking to maximize fun will have a different motivation than a student who feels pressure to do well on an assigned task—that is, players want to keep playing, while test-takers want to end the experience as soon as possible.

Authors (2006) have reviewed several different types of supportive tools commonly found in computer-based games—for instance, “full walkthroughs” that give comprehensive instructions for solving puzzles or strategies for overcoming challenges, and “treasure maps” that reveal the locations of hidden valuables. Note that many supportive tools are developed by players (rather than designers) who are motivated by the desire to earn respect or thanks from other players in their communities. However, the results of their innovations make them worthy of attention from educational game developers.

6. Conclusion

Our findings suggest mixed effects of supportive tools on player learning potential, sometimes exerting a positive effect in the form of reducing frustration, at other times a negative effect in the form of increased reliance on available support. Our data also support the idea that different scaffold types play different roles in learning. Note that all of the scaffolding tools used in this study were designed to assist recreational game players, with no consideration for their effects on learning. Our purpose was to determine how such tools might be used in learning contexts.

How scaffolding should be adequately provided to learners is a key issue (Luckin, 2008; Walqui, 2006; Wood et al., 1976). Our findings indicate that digital scaffolding can boost motivation for learning while enhancing game performance. Effective scaffolding can bridge the gap between learner capabilities and goal expectations, helping students internalize knowledge from interactions with scaffolds while independently achieving their goals (Rogoff & Gardner, 1984). The near-instant feedback that many games offer can increase learning opportunities, but the overuse of error alert tools for controlling frustration likely inhibits student development of heuristic solutions. Our findings suggest that guidance elaboration can concurrently prevent students from being stuck in games and help them learn problem-solving principles. Consequently, students will more likely use heuristic tools to develop advanced strategies based on a more thorough understanding of those principles.

The challenge for instructors is to find a balance between supportive tool availability and encouraging learners to accept some level of frustration from game bottlenecks (Rogoff, 1990,Yelland & Masters, 2007). When providing scaffolding, instructors should observe the autonomous problem-solving behaviors of their students, identify their difficulties, and offer adequate assistance. As mentioned earlier, most game players avoid using supportive tools in order to maintain a sense of fun, and educational game developers may be able to use this characteristic when making design decisions regarding scaffolding. If such tools can be used in support of increasingly stronger and more detailed diagnostic functions, they can exert considerable positive effects on learning.

Finally, scaffolding tools currently used in existing games are designed to address the general needs of all players regardless of their level of proficiency, and therefore have two major drawbacks. First, players need different and more complex support tools once they develop the required skills to use higher-order solving strategies; more general scaffolds may not provide the continuous support required by learners at Vygotsky's advanced ZPD level. Second, rookie players may require less complex support than that offered by commercial game companies. Given access to scaffolds, new players may be able to solve tasks, but not really understand why, how, or when to use support tools; as a result, they may rely on those tools too much at first, thus reducing the sense of fun that is central to gaming. Again, this problem may be resolved by designing different levels of scaffold tools that instructors can control (including a "scaffold removal" option) to increase the teaching effectiveness of educational games.

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