Video Games: A Significant Cognitive Artifact of Contemporary Youth Culture

Lyn Henderson
School of Education
James Cook University
Townsville. Australia. 4811
61 747 814355
edldh@jcu.edu.au

ABSTRACT
Video games are not just an important cultural artifact of youth culture but have considerable cognitive worth. Centered within an information processing theory and mediating processes' framework, the empirical qualitative study investigated, via stimulated recall methods, the thinking skills and strategies of five teenagers while playing an action-adventure video game. Sixteen types and 600 instances of cognitive skills and 11 types and 155 instances of cognitive strategies were identified. The thinking skills included high engagement with school valued cognitive skills, such as metacognition, and deduction and induction strategies. The findings support the informal educative value of playing recreation video games and their inclusion in schools.

Keywords
Thinking skills, strategies, video games, metacognition, teenagers, stimulated recall

Education is not limited to formal schooling; hence, cognitive processes are broader than those taught and tested in school. As part of our informal education, playing games has been identified as an important facilitator of cognitive development [1, 2]. Recreational video games played with a hand console connected to the television have been relatively ignored as a means of informal education. Indeed, they are usually seen as trivial without educational worth beyond eye-hand coordination and something from which educators, parents, and politicians must rescue children and distance themselves. Yet video game literacy demands mastery of significant cognitive skills. Players need to figure out the rules of the game by various strategies and a process of hypothesis testing. Teenagers create dynamic mental representational systems as they work out

Proceedings of DiGRA 2005 Conference: Changing Views – Worlds in Play.

how the consol buttons and screen symbols, icons, and images act individually and in unison. Video games require the player to attend simultaneously and selectively to a number of different pieces of information displayed on the screen; that is, to develop the skill of parallel processing or multiplex thinking [3]. This study is interested in the recreational video game as a means of informal education. It explores the cognitive skills and strategies used in real world, as opposed to formal educative situations, that is, in everyday cognition.

LITERATURE REVIEW

Unfortunately, there is a remarkably limited research literature in this area. Most merely infer that certain thinking skills and strategies occurred based on the games' structure and on learning theory, for example [4, 5, 6]. Mislevy [7] calls such assessment "reverse reasoning, or induction". Some research on recreational video gaming is more targeted. A popular theme is spatial relations ability, spatial visualization, and perceptual speed, coupled with gender, age, or video game practice [8]. Transfer of cognitive skills used in recreation video game playing to formal educational settings is a minor focus [9]. Others [10] demonstrated that video/computer game players are called on to reason inductively and deductively, make interferences across screens, and reason metacognitively. Research [11] supported the use of critical thinking skills while adventure and strategy games allowed time for reflective decision making [12]. This recreation video game research included males and females ranging from four to 18 year olds, with a heavy emphasis on the 10-12 year group and young undergraduates; some of this research was with action games.

Research Aim

The research goal was to investigate (ascertain, categorise, and analyze) the thinking skills and strategies utilised by five teenagers when playing a recreation (as opposed to a school-based education) video game, *Final Fantasy IX*. It was speculated that participants would demonstrate a range of (a) thinking skills, from the higher order skills of metacognition to the lower skill of recall and (b) thinking strategies, such as trial and error and deductive reasoning; and that (c) some thinking skills and strategies would be utilised more than others. Overall, it aimed to answer one key question: Does playing a recreational video game demonstrate a wide range of thinking skills and strategies that are valued in formal education classrooms?

METHODOLOGY

This was a qualitative empirical study contextualized within information processing theory and the mediating process paradigm. Simplistically, the information processing theory explains how learning and remembering occur through receiving incoming stimuli (from the video game) into sensory memory where it is either discarded or sent to short-term working memory. Then it is processed and sent to long term memory for categorized storage from which, when needed, it is retrieved back into short term memory and then delivered as outcomes [13, 14]. The mediating process paradigm focuses on thought processes that are involved in processing information and thus mediate, or come between, stimuli (the video game) and outcomes (playing and solving the game) [15]. Thus, it does not rely on reverse reasoning claims based on the behaviourist input-product paradigm [16]. Mediating processes can be viewed as the fine-grained elements of cognition through which, and by which, everyday cognitive outcomes are realized. Introspective process tracing methodology is then utilised to access those processes based on the tested assumption that a student can access their mental processes at some level and verbalize their thoughts [17, 18, 19]. Stimulated recall interviews were used as an introspection tool [17, 20] to elicit those thoughts.

Participants

Five 13 year old teenagers, four male and one female, volunteered and self-selected their pseudonyms. They had played recreation video games for at least two years, including both action and roleplay, and were therefore defined as competent game players. Such players, rather than those new to the video game genre, would establish a benchmark for future research. The students all attended the same school and were all taught by the teacher who identified their academic abilities based on the school's assessment results: 2 (1 male and 1 female) were identified as of very high ability and one each of average, low, and very low ability. The age group was chosen mainly because there is a lack of research with this age group in the cognitive area of recreational video game playing and because they would be more able to verbalize their thoughts during the prompted stimulated recall interview in comparison with younger primary aged children. The researchers had met all seven student volunteers and parents at the Pizza Hut when explaining what would be involved if they wished to continue. All but two continued. Another interaction occurred with a parent and interviewee either on the phone or face-to-face when arranging the interview schedule.

Video Game

Because the lack of interest in a game chosen by the researcher has negatively affected results [21], participants were asked to nominate video games. The fantasy action-role play video game, *Final Fantasy IX*, was chosen because it had not been played by any participant. The game has an Australian censorship "Mature rating suitable for teenagers". Parents approved the choice knowing it contained low level violence, that is, fighting by human and cartoon characters who can be brought back to life – given health – through potions. It contained no "blood and gore" or first person fighting.

Data Collection Techniques and Coding

A 50 minute video and audio taped interview was conducted with each participant because the parents had stipulated a one hour maximum for the interview and setting up and dismantling the equipment. However, there was some slight variation in the length of the interview as each player was stopped at the same part of the game to help maximize credibility and reliability of the data. Depending on parental choice, the research was conducted in either the teenagers' regular home video game playing environment, the lounge/family room, or in a lounge-type area at the university to help promote context authenticity. An audiotaped stimulated recall interview was conducted at the beginning of the game with each participant to obtain an initial benchmark as novice players with this particular game. Researchers [10] established the worth of the "expert game player" as an interviewer. This research copied this strategy but utilized the expert game player as co-interviewer as the principal investigator had expertise with the stimulated recall methodology.

The prompted stimulated recall technique is designed to probe participants' thoughts during a particular activity. In this study, it was playing *Final Fantasy IX*. Various researchers (e.g., [19, 22] have shown that stimulated recall is a reliable tool, that has high trustworthiness and credibility of obtaining accurate recall if the interview (a) includes visual (video game) and oral (interviewer) prompts [22], (b) is conducted within 48 hours of the event [18, 22, 23, 24] and (c) adheres to strict interview protocols [18, 22]. This study avoided the "more invasive" think-aloud method [25] because it is difficult for participants to simultaneously perform a set task and verbalize their thinking as they are problem solving that task [23, 24, 26]. Training is stipulated to help counteract this difficulty [22]. This project therefore maximized the data's credibility, particularly as the 50 minute stimulated recall interview was conducted during the game play, required the teenagers to stop playing to report their thoughts, and did not need the participants to be trained. The principal researcher however did train the co-researcher in how to conduct stimulated recall interviews.

Each teenager was invited to pause the video game to report their thoughts and actions and was advised that either interviewer would ask the teenager to stop playing and recall their thoughts at what appeared to be significant times. For instance, questions such as, "What were thinking when you chose the money token?", occurred at points where the teenagers had selected a token or weapon to buy or sell; when they laughed or groaned; when they had paused for a while before recommencing play; or when the controlled character seemed to be wandering aimlessly. Confirmatory questions (e.g., "Did you think that back then when you groaned or just now when I asked you?") attempted to ensure that the reported thoughts had occurred when they were playing the game rather than during the interview. A particular strength of stimulated recall is that, through adhering to this protocol, it can "successfully avoid the 'pious bias' of self-report data devoid of context" [26]. Research [27, 28] revealed that "we compensate for failing to recover specific details about a past episode by drawing inferences and then mistake these inferences for something that we had experienced … and fill in omissions that were not present because they are typical of that kind of situation [28]. An example would be typing http://www.scholar.google.com when searching for articles on teenagers and video game research because the regular google address includes "www". Adhering to stimulated recall protocols also avoids the associated problem where the researcher 'leads the witness' in discrete interviews without having observed [18, 22] the player playing that game. For example, the researcher's question, "Please tell me about the strategies you use when playing a video game like *Final Fantasy IX"*, would elicit data that could be based on that participant's actual strategies, an amalgam of what his peers told him they use, or what he thinks may give him most status in the researcher's eyes, given that the researcher had not witnessed the game play.

The tapes were transcribed allowing the data to be coded and categorized, with the video tape used as a confirmatory check on the audio tape's transcription and as a memory aid. The transcript was divided into segments that related to one prompted question and response or a participant's self- report. The identified categories of the thinking skills were informed by previous research [19, 29, 30] while the cognitive strategies emerged from the data. When coding each subsequent transcript, the previous transcript categories were consulted to ensure standardization across all transcripts. Another researcher very conversant with stimulated recall also randomly checked the categorizations in all transcripts as categorization progressed and at the conclusion. When there was a difference, consensus through justification of the rationale for that categorization occurred in all five instances.

The following table provides definitions for the 18 thinking skills identified in this study.

Table 1: Definitions of Thinking Skills

Type	Description Mental activity in which the participant: -
Affect (Feelings)	reports feelings aroused by the video game (VG); includes empathy with characters
Analyzing	reduces, breaks down whole (e.g., problem, task) into parts
Anticipating	wonders about the possibility of an event, relevance of material, or content
Applying	considers the use of an idea, tactic in a different context.
Categorizing	sorts items (various tokens), ideas, skills into different groups
Comparing	identifies similarities, differences between two statements, concepts, models, situations, ideas, points-of-view, etc.
Confirming	judges that the ideas in the VG support one's own practices, tactics; verifies their game play actions, thoughts, and significance of certain characters and symbols
Diagnosing	identifies strengths and weaknesses in idea, strategies, points-of-view

Evaluating	the worthwhileness of the game itself, activities, own game strategies, graphics, etc.
Generating	formulates one's own questions, examples, ideas, or problems; interpolating; going beyond what was in the VG
Imaging	creates a mental image of an idea in the text, movie, animation, or graphic in order to gain a fuller understanding
Judging	questions issues of morality, such as cheating, stealing, slavery, and kidnapping
Justifying	rationalizing, explaining, and providing reasons for their actions and thoughts
Linking	associates or brings together two or more ideas, topics, experiences, tasks
Metacognizing	thinks about, reflects on, evaluates their certainty of understanding; directs own thinking suggesting ways to troubleshoot lack of comprehension
Recalling	brings back into working memory an idea, opinion, fact stored in long-term memory
Reflecting	general indication of careful consideration over past action and response
Translating	using their own words to interpret, explicate, and clarify the story, what is happening, role of characters

Two examples of how the thinking skills and strategies were categorized will suffice.

First, the example from the categorization of thinking skills is presented:

Interviewer: What were you thinking as you were reading the note?

Tony: I was thinking, ‘Oh, now I have to kidnap someone. This is getting worse!’

Tony’s first sentence was coded as a *confirming* thinking skill because it confirmed what was on the screen while the second was categorized as *evaluating* (the worth of what he had to do).

The second example demonstrates how strategies (and thinking skills) were categorized:

Interviewer: Can you tell us what you were thinking as the character was running?

Eyore: I was thinking that I know I need to find out what the buttons do (*metacognitive thinking skill; Table 1*) before I have to go fight someone again (*justification thinking skill; Table 1*). So, if I pressed the circle - that made it go fast. So, now I thought, if I press the triangle {pause} that thing popped up (***trial and error strategy***). That's strange! (*evaluation thinking skill; Table 1*).

Eyore was using a trial and error strategy with the console buttons. She also had a specific reason for doing so, improving her chances in a fight as she had not done well in her first fight. As she revealed later in the game, Eyore maintained a trial and error strategy with the buttons and combinations of buttons as she continued playing the game.

Answers to any questions that directed the interviewee were discarded. One glaring example occurred during the third interview, "Did you predict that your character would do that?", and Robot's answer was regretfully discarded.

RESULTS

Table 2 delineates the number of categorized thinking skills and strategies from the participants stimulated recall interviews.

Table 2: Identified Thinking Skills and Strategies when Playing *Final Fantasy IX*

Thinking skills	Tony	Eyore	Robot	Tuck	Zeus	Total	Strategies	Tony	Eyore	Robot	Tuck	Zeus	Total
	V H	VH	A	L	VL			VH	VH	A	L	VL	
Predicting	36	20	40	16	23	135	Explore	5	4	19	1	4	**33**
Evaluating	33	14	18	1	8	74	Trial&Error	7	9	7	3	2	**28**
Justifying	13	14	20	11	10	68	Deduction	6	3	9	5	2	**25**
Confirming	15	4	19	6	11	55	Equip	7	5	3	0	0	**15**
Metacognizing	11	7	16	5	7	46	Induction	4	4	2	1	2	**13**
Translating	9	7	8	3	4	31	Talking	3	4	4	0	2	**13**
Feeling	14	5	6	1	3	29	Recheck	2	2	4	0	2	**10**

Linking	5	8	8	1	4	26	Movies	1	1	2	0	1	**5**
Categorizing	6	2	9	6	0	23	Potions	0	2	0	1	2	**5**
Comparing	1	17	3	1	0	22	Attack	1	1	0	2	0	**4**
Generating	12	4	5	0	0	21	Values	3	0	1	0	0	**4**
Analyzing	5	0	7	0	0	12							
Diagnosing	0	1	0	0	2	3							
Imaging	2	0	0	0	0	2	**VH** = Very High Ability **L** = Low Ability						
Applying	1	0	0	0	1	2	**A** = Average Ability **VL** = Very Low Ability						
Recalling	1	0	1	0	0	2							
Total	**190**	**111**	**170**	**54**	**75**	**600**	**Total**	**39**	**35**	**51**	**13**	**17**	**155**

Thinking Skills and Strategies

Sixteen types and a total of 600 instances of thinking skills were reported as being utilised during the students' first encounter with the game (Table 2). In comparison, 11 types and 155 instances of strategies were identified from the data. It is a more than pleasing result given that the teenagers had only played for a short period of time (50 minutes less that spent reporting their recalled thoughts and that taken by the researchers' prompts). As surmised, there were notable variations in the recalled instances for the various types of skills and strategies. Thinking skills had a more significant player range from 135 to two instances whereas their strategies ranged from 33 to four (Table 2).

With respect to their reported thinking skills, there was a significant drop of 61 points from the highest thinking skill, predicting (135 instances), to the second highest with 74 instances reported for evaluating, and then a fairly regular decline between the remaining thinking skills down to a low 2 instances each for applying, imaging, and recalling (see Table 1 for definitions). The first three strategies (Table 2) – explore, trial and error, and deduction - were fairly evenly spaced with a drop of ten points down to the next grouping of equipping, induction, talking (to the characters), and rechecking. The next grouping in Table 2 were strategies typically used in action-roleplay games: watching the movies for hints as to what may be needed or avoided during the game, using potions on themselves to return to health or damage the enemy, and choosing to attack. The last one in this grouping, values, was only used by three of the players when they placed values on strategy decisions when issues of morality arose when they agreed to kidnap (Tony), become a slave (Robot; Tony), and condone cheating (Tony) in order to get further into the game.

What is also obvious from Table 2 is that all five teenagers used higher order thinking skills, such as, evaluating (74), justifying (68), and 46 instances of the meta-thinking skill, metacognition, There was also an agreeable number of other reported cognitive skills that were used by all the teenagers such as confirming (55 instances), translating (31 instances), and linking various aspects of this game with other games they had played (26). They all mentioned thinking about their feelings in one or more of the following 29 instances: humour, with the language used by some of the characters (all but Eyore), surprise when the game took an unexpected turn (all the teenagers), success in solving a problem (Robot), anxiety about their inability to find Alleyway Jack, for example (Eyore & Robot), annoyance with their poor fighting abilities (Eyore and Tony) and having no way to move past the movies (Tuck), sadness because the princess was crying (Tony), and delighted pride from Zeus when he did well in the complicated card game.

The five teenagers engaged unevenly in some types of thinking skills (Table 2). The most glaring was evaluation (with a range from 33 to 1), others included comparison (17 to 0); generating (12 to 0), judging (12 to 1), feelings (affect) (14 to 1), confirming (19 to 4), and metacognition (16 to 5). The teenagers reported uneven instances for strategies but not so striking a range as for thinking skills, with the exception of exploring, which had a significant 19-1 range. What is glaringly obvious are the low instances of strategies reported by Tuck and Zeus; they are approximately 20 instances lower than the other three players' scores.

The results confirmed that recreational video games can elicit valued cognitive skills and strategies from players of various teacher-identified academic abilities when playing video games, specifically *Final Fantasy IX*.

DISCUSSION

The paper so far has presented thinking skills and strategies as if they are separate. This approach was, of course, a contrivance to tease out the two cognitive aspects of the teenagers' game playing. Obviously, each teenager's thinking and strategizing were intertwined during their game play. Therefore an exploration is warranted of the plausible reasons for the discrepancies among the various teacher-identified ability level students and their reported instances of thinking skills and strategies. In doing this, the crucial aspects of certain skills and strategies, and the links between these, will throw light on the players' thinking and strategizing.

Informal cognition versus school rated ability levels

If we compare the rank order of the teenagers reported thinking skills and strategies when playing a recreation video game with their teacher-identified school ability levels, then there are some striking incongruities (Table 3). The most notable is the reversal of Eyore (Very High) and Robot (Average) and that of Tuck (Low) and Zeus (Very Low). There are also notable differences with the average-rated Robot reporting more instances of strategies than both the very high students (Table 3). Plausible reasons could be incorrect school ratings and/or the inability of students to report more of their thinking. Another relevant reason is the contention of advocates [3, 4, 5] who repeatedly proclaim the educational worth of playing video games. Their contention is that students like Robot, Tuck, and Zeus are switched-off at school but not when playing a video game that demanded thoughtful involvement. Hence, their reported levels

Table 3: Comparison of Teenagers' Game Playing Thinking Skills and Strategies

with their Teacher-Identified School Ability Levels

Teenagers	Teacher-rated ability level	Thinking Skills	Strategies	Totals
Tony	Very high	190	39	**229**
Eyore	Very high	111	35	**146**
Robot	Average	170	51	**221**
Tuck	Low	54	13	**67**
Zeus	Very low	75	17	**92**

of cognitive skills and strategies should not be a surprise. However, these reasons are inadequate and a more detailed analysis is warranted.

Metacognition (Table 1) is considered to be the most important cognitive skill for success [31, 32]. Metacognition can be divided into two parts: awareness and troubleshooting [19]. The lower level of metacognition is *awareness of* our (a) focus and nature of thinking; (b) capacity for coping with tasks, that is, knowing whether we know we are correct or incorrect. The more crucial aspect of metacognition is being in *control of* directing oneself to (a) focus on the immediate specific task, (b) formulate questions and answer them, (c) maintain an analysis of what I know and my ability to carry out a task, and importantly, (d) formulate strategies to take to troubleshoot perceived cognitive weaknesses in thinking and strategizing to solve the problem [19].

All five players demonstrated use of both the awareness and control types of metacognition. Examples of awareness metacognition include the following. Robot stopped the game and confidently reported, “I was thinking I know; I know how to solve this.” Tuck reported, “I got it wrong, but I don’t know why?” However, the next example delineating control metacognition is Tuck’s subsequent reported thought, “Okay. I have to find Alleyway Jack to get help.” This exemplifies Tuck’s ability to troubleshoot his perceived lack of knowledge by formulating a plan of action. Nevertheless, there were more instances of awareness (27) than control (19) metacognition.

Research [33, 34] revealed that high achievers report using more self-regulated cognitive skills than do lower achievers. This was not replicated in this study. Robot who was identified by the teacher as of average ability, recorded the highest number of metacognitive skills with an 8:8 awareness versus control breakdown compared with the very high rated teenagers, Tony (6:5) and Eyore (5:2) Yet the very low ability rated student, Zeus, equaled Eyore’s score of seven but recorded 4:3 breakdown while the low ability Tuck recalled the lowest ratio, 4:1, of awareness versus control metacognitive skills. Obviously, this is still a result that indicates lower rated students can utilize valued skills that the school would not think possible for that academic rating.

Nevertheless, if we couple these results with the evaluating thinking skill, their levels of metacognition are corroborated. Tuck did not self-evaluate his game playing yet the other teenagers did. Tony engaging in 18 self-evaluations, Robot 12, Eyore used half her evaluations for self-evaluation, and Zeus targeted only three of his eight evaluations to his game play. Neither did Tuck or Zeus report using the cognitive skill of reflection by carefully considering their past actions and responses to those actions (Tables 1 & 2). It appears that there could be a close relationship between the players’ control metacognition, self-evaluation of task performance, and careful reflection on past activities and responses, and that this warrants further research. A review study [35] concluded that students with higher-order metacognitive abilities tended to have lower computer anxiety. Based on this finding, it is plausible that Eyore’s four reported bouts of anxiety and, less so, Tuck’s one reported attack perhaps affected their ability to engage in the higher order skills just discussed.

Further insights are available through exploration of their strategies and the strategies’ relationships to this line of argument. Given the genre and that the teenagers were just beginning a new game, it is not surprising that the top two strategies (Table 2) were exploration (33) and trial and error (28), which is a legitimate problem solving approach though not the most efficient

[36]. Furthermore, they were utilized by all five players. However, both can be subdivided into strategies that involved varying levels of thinking skills. All players either wandered aimlessly, “I wasn’t thinking anything, just walking around” (Zeus), or they explored with thoughtful consideration, “I was thinking, ‘I have to find out what that shop is selling and if it’s worth coming back later to buy equipment’” (Zeus). All of Eyore’s, three each of Tony’s and Zeus’s explorations were thoughtful with Robot reporting 11 of his 19 instances as deliberate “missions” (Table 2). Their few trial and error strategies (Table 2) were similarly divided between a hit-and-miss, “I’ll just try this out to see what happens” (Tony), and “if I do this, I could find a token” (Robot). This last type involves prediction, the highest thinking skill used by all players (Table 2). The more rigorous types of cognitive strategies, deduction and induction, together accounted for a sound number of instances (38, Table 2) during the short playing time. It was unusual to find that Tuck used deductive reasoning a surprising number of times (5) given his record on other strategies and thinking skills and particularly in comparison with the other players (Table 3). Perhaps he reported what he was thinking when the interviewer asked him, and not what he had actually thought, even though confirmatory questions were asked. Perhaps he was experiencing working memory overload and therefore could not report the thinking skills only the actual strategy or

Targeting Players

Eyore had the highest number of reported trial and error strategies (Table 2). When this is combined with both her thoughtful exploration strategy, her two thorough and long re-checks to ensure that she had not missed anything, and her reflections, it is somewhat incomprehensible that this combination did not have a greater effect on her metacognitive and self-evaluation thinking skills. Perhaps she concentrated too much on comparing the game with other games (17 instances) when the other players used this skill minimally (Table 2). Also, it was very likely that she was laying solid foundations when she continued playing with the game in order to “feel on top of it”.

Robot, teacher-rated as average, did not have the highest number of reported skills and strategies but it was only eight fewer than that of Tony, rated as having very high abilities (Table 3). Why was Robot’s achievement so accomplished? Even if we take out the instances in which all players utilized lower level metacognitive and evaluative thinking skills, this claim still holds. He was not more expert than Tony and Eyore with respect to playing games with the same genres as *Final Fantasy IX*. It is plausible to suggest that it was the combination of Robot’s skills and strategies. These were the purposeful exploration, deduction, induction, predicting, evaluation of his game play, control metacognition, justification of his reasoning, and reflecting on his game play. Tony and Robot were fairly even on their scores for most of these thinking skills. Both also analyzed tasks and strategy problems by breaking them down into parts. His high number of considered explorations helped give him a holistic overview that would have supported his cognitive abilities. The research revealed that Robot utilized the full process of hypothesizing four times during this short period. This was a characteristic of Tony’s play, too, as it was for Zeus and Eyore (but not for Tuck). However more of their hypotheses collapsed, that is, Tony, Eyore and Zeus did not complete the steps required for it to be categorized as a hypothesis process.

CONCLUSION

There are four major areas of significance arising from the research. First, even within such a short time-frame as this research episode, the data revealed that playing a recreation video game provided beneficial informal educative experiences. Second, the study provides support for the unsubstantiated claims of the cognitive worth of playing games. Third, it contradicts popular opinion by confirming that recreation video games are a significant cognitive artifact of youth culture. Fourth is the viability of stimulated recall as a methodological tool in game research.

The major implications are that, because the research has proven worthwhile, it therefore warrants (a) replication studies targeting various age groups, gender, multi-players, and game genres, and (b) identifying what cognitive complexities and the game triggers of the when and how of parallel processing. Another important implication is that teachers need to acknowledge the cognitive worth of digital games for school-rated average, low, and very low ability students and develop ways to ensure that there is transfer of such valued skills and strategies into classrooms. Although it cannot be generalized, this study has revealed that certain digital games deserve a cognitive educative role in schools.

REFERENCES

1. Reiber, L. P. "Seriously considering play: Designing interactive learning environments based on the blending of microworlds, simulations, and games" in *Educational Technology Research and Development*, vol. 44, no. 2 (1996), pp.43-58.

2. Nikolopolou, A. "Play, cognitive development, and the social world: Piaget, Vygotsky, and beyond" in *Human Development,* no. 36 (1993), pp.1–23.

3. Prensky, M. *Digital Game-Based Learning*, McGraw-Hill, New York, 2000

4. Gee, J.P. (2003). *What Video Games Have to Teach Us about Learning and Literacy.* New York: Palgrave Macmillan.

5. Kirriemuir, J., and McFarlane, A. *Literature review in games and learning*. Report 8. Bristol: NESTA Futurelab, 2004. Available at http://www.nestafuturelab.org/research/reviews/08_01.htm

6. Stapleton, A.J. and Taylor, P.C. "Why videogames are cool and school sucks!" Paper presented at Australian Game Developers Conference (Melbourne, Australia, 20-23 November, 2003).

7. Mislevy, R.J., Steinberg, L.S., and Almond, R.G. *On the structure of educational assessments. CSE Technical Report 159*. Los Angeles, CA: Center for the Study of Evaluation, Centre for Research on Evaluation, Standards, and Student Testing (May 2003), p.11.

8. *Journal of Applied Developmental Psychology*, vol. 15 (1994), Special Edition (entire volume)

9. Camioni, L., Ercolani, A., Perrucchini, P., & Greenfield, P. "Video games and cognitive ability: The transfer hypothesis" in *Italian Journal of Psychology,* vol. 17, no. 2 (1990), pp.331-348.

10. Pillay, H., Brownlee, J., and Wilss, L.. Cognition and recreational computer games: Implications for educational technology. *Journal of Research on Computing in Education,* vol. 32, no. 1 (1999), pp.203-216.

11. Keller, S. *Children and the Nintendo*. ERIC document No.405069, 1992.

12.Greenfield, P., Camaioni, L., Ercolani, P., Weiss, L., Lauber, B., & Perucchini, P. "Cognitive socialization by computer games in two cultures: Inductive discovery or mastery of an iconic code?" in *Journal of Applied Developmental Psychology*, vol. 15, no. 1 (1994), pp.59-86.

13. Atkinson, R., & Shiffrin, R. Human memory: A proposed system and its control processes in K. Spence & J. Spence (Eds.), *The Psychology of Learning and Motivation. Advances in Research and Theory*, Vol. 2, Academic Press, New York, 1968.

14. Craik, F., & Lockhart, R. "Levels of processing: A framework for memory research" in *Journal of Verbal Learning and Verbal Behavior,* vol. 11 (1972), pp.671-684.

15. Herrman, D., Raybeck, D., & Gutman, D. *Improving Student Memory*, Hogrefe and Huber Publishers, Seattle, 1993.

16. Miller, G. "The magical number seven, plus or minus two: Some limits on our capacity for processing information" in *The Psychological Review,* vol. 63 (1956), pp 81-97.

17. Doyle, W. "Paradigms in teacher effectiveness research", Paper presented at Annual Meeting of the American Educational Research Association (April, 1975). Available at http://www.education.ucsb.edu/ ~ed219b/Doyle.html

18. Henderson, L., and Tallman, J. *Mental Models, Stimulated Recall and Teaching Computer Information Literacy*, Scarecrow Press, Lanham WD, in press.

19. Marland, P.W., Patching, W.G., and Putt, I. *Learning from Text. Glimpses Inside the Minds of Distance Learners*: James Cook University of North Queensland, Townsville, 1992.

20. Vermersch, P. "Introspection as practice" in *Journal of Consciousness Studies*, vol. 6, no. 2-3 (1999), pp.17-42

21. Greenfield, P., Brannon, D., and Lohr, D. "Two-dimensional representation of movement through three-dimensional space: The role of video game expertise" in *Journal of Applied Developmental Psychology*, vol. 15, no. 1 (1994), pp.87-103.

22. Gass, S.M., and Mackey, A. *Stimulated Recall Methodology in Second Language Research,* Lawrence Erlbaum, Mahwah, New Jersey, 2000.

23. Bloom, B. "The thought process of students in discussion" in S.J. French (Ed.), *Accent on Teaching: Experiments in General Education*, Harper & Row, New York, 1954, pp.23-46.

24. Ericsson, K., and Simon. H. "Verbal reports as data" in *Psychological Review*, vol. 87, no. 3 (1980), pp.215-251.

25. Karasti, H. "Using video to join analysis of work practice and system design: A study of an experimental teleradiology system and its redesign" *IRIS 2000 Conference*. Available at http://iris.informatikgu.se/conference/ iris20/31.htm

26. Meade, P., and McMeniman, M. "Stimulated recall: An effective methodology for examining successful teaching in science" in *Australian Educational Researcher*, vol. 19, no. 3 (1992), pp.1-18.

27. Reder, L. "Plausibility judgments versus fact retrieval: Alternative strategies for sentence verification" in *Psychological Review*, vol. 89 (1982), pp.250-280.

28. Hannigan, S., and Reinitz, M. "A demonstration and comparison of two types of inference-based memory errors" in *Journal of Experimental Psychology: Learning, Memory, and Cognition*, vol. 27, no. 4 (2001), pp.931-940.

29. Henderson, M. *Multimedia Interactivity: An Investigation into Learners' Mediating Processes during Click-Ddrag Activities,* Unpublished B.Ed. Hons, James Cook University, Townsville, 1996.

30. Pausawasdi, N. *Students' Engagement and Disengagement when Learning with IMM in Mass Lectures*. PhD Thesis, James Cook University, Townsville, 2001.

31. Halpern, D.F. *Thought and Knowledge: An Introduction to Critical Thinking*, Erlbaum Associates, Mahwah, NJ., 1996.

32. Gravill, J.I., Compeau, D.R., & Marcloin, B.L. "Metacognition in IT: The influence of self-efficacy and self-awareness" in *Human-Computer Interaction Studies* in *MIS*: *Eighth Americas Conference on Information Systems*, (2002), pp.1055-1067.

33. Pintrich, P.R., & DeGroot, E.V. "Motivational and self-regulated learning components of classroom academic performance" in *Journal of Educational Psychology,* vol. 82 (1990), pp.33-40.

34. Van Zile Tamsen, C., and Livingston, J.A. "The differential impact of motivation on the self-regulated learning of high and low achievers" in *Journal of College Student Development*, vol. 40 (1999), pp.54-59

35. Tsai, M., and Tsai, C. "Student computer achievement, attitude, and anxiety: The role of learning strategies" in Journal of Educational Computing Research, vol. 28, no. 1 (2003), pp.47-61.

36. Martinez, M. "What is problem solving?" in *Phi Delta Kappan,* vol. 79 (1998), pp.605-609.