

GPBL: An Effective way to Improve Critical Thinking and Problem Solving skills in Engineering Education

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Abstract: There are various active learning strategies like Game based Learning (GBL), Puzzle based Learning (PBL), Project based Learning, Problem based Learning etc to improve students' knowledge. Puzzle based learning (PBL) can be used to attract, motivate, and retain students as well as to improve the critical thinking and problem solving ability of students. Similarly Game based Learning (GBL) can also be used to promote students' interest and engagement, and provide immediate feedback on performance. Hence in this study, I designed the GPBL (Game and Puzzle based Learning) which is the combination of the PBL and GBL to improve the critical thinking and problem solving ability of students. So in GPBL, Crossword puzzle, word search puzzle, word scramble puzzle and word match puzzle are considered while game considered is snake and Ladder game. This activity was conducted for the course Digital Technique of Second Year Computer Science and Engineering. Twelve puzzles (three Crossword puzzles, three Word Search puzzles, three Word Matching puzzles and three Word Scramble puzzles) and three Snake and Ladder games are considered as a part of this GPBL activity which covers the syllabus of the course Digital Technique. Also the feedback related to this activity is presented

Keywords: Game based Learning (GBL), Puzzle based Learning (PBL), Crossword Puzzle, Word Search Puzzle, Word Matching Puzzle, Word Scramble, Snake and Ladder, Game and Puzzle based Learning (GPBL)

1. Introduction

Active learning instructional strategies can be used to engage students in (a) thinking critically or creatively, (b) speaking with a partner, in a small group, or with the entire class, (c) expressing ideas through writing, (d) exploring personal attitudes and values, (e) giving and receiving feedback, and (f) reflecting upon the learning process (Jim Eison, 2010). Introduction of active learning strategies in the teaching-learning process provides instructors with an opportunity to engage students and enhance their learning process (Bailey, Hsu, & DiCarlo, 1999; Dimmock, 2000; Roche, Alsharif, & Ogybadeniyi, 2004).

Now days it is required to provide students with alternative methods to the traditional method of learning in teaching-learning process (Htwe, Sabaridah, Rajyaguru, & Mazidah, 2012). There are learning methodologies like problem-based learning and project-based learning which deals with quite complex situation (e.g. Blumenfeld et al. 1991, Bransford et. al. 1986). Leong (2005) recommended class activities such as term papers, cases and projects

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as a way of ensuring students' active involvement in the learning process. Hence Active-learning strategies used into classroom allows instructor to engage students in the learning process and make their learning experience more effective, efficient and meaningful (Graffam,2007). Creating learning environment which are student centred facilitate active learning (Michael,2006)

Stewart, Brown, Clavier and Wyatt (2011) explained the positive role active learning plays in teaching-learning process for enhancing students' learning. Saxena, Nesbitt, Pahwa and Mills(2009) found that incorporation of active learning strategies into the curriculum can improve understanding and learning.

Puzzle based learning (PBL) is used to promote critical thinking skills that can set a foundation for problem-solving in future course work (Zbigniew Michalewicz, Nickolas Falkner, Raja Sooriamurthi).

Game based learning (GBL) is referred to the use of games in teaching and learning process (Carlo Perrotta et. al.) Game based learning has been proven to be very powerful in engaging learner's attention for a longer span of time.

Games and puzzles have been proved to be effective methods of the active learning in teaching-learning process (Persky, Stegall-Zanation, & Dupuis, 2007; Poston, 1988). These games and puzzles based learning facilitate important critical-thinking and problem solving (Childers, 1996; Eckert et al., 2004).

Hence in this paper, I designed the GPBL (Game and Puzzle based Learning) which is Puzzle based as well as game based learning and conducted this activity for the course Digital Technique of Second Year Computer Science and Engineering.

2. Related Work

Lewis and Mierzwa (1989) suggest that games such as crossword puzzles, board games, word searches etc. are effective teaching aids. Varieties of games, such as crossword puzzles have been successfully used in the classroom and also have proved that such games can improve the students' understanding and create a positive impact on student learning (Martinez & Parra, 2011; Leong, 2005; Saunders and Christopher, 2003)

Dr.Runki Saran, Dr. Saurabh Kumar(2015) used crossword puzzle as a teaching tool in dental materials and evaluate students' perception about the same while Childers (1996) and Shah, Lynch, and Macias-Moriarity (2010) reported use of crossword puzzle as enjoyable and helpful activity. Also crossword puzzles make studying more enjoyable and used as a supplement to traditional methods (Moore & Dettlaff, 2005) and these puzzles have a positive effect on learning (Weisskirch,2006)

Sanjay Gupta et. al. found the student motivation and participation high as evidenced by the high number of cross word puzzles attempted, on average, by each student while Massey, Brown and Johnston (2005) used crossword puzzles for homework assignments. Babayemi, J.O (2014) examined the effects of crossword-picture puzzle (CPP) and mental ability on students' achievement in Basic Science. Bolorunduro (2005) reported a significant contribution of puzzle-based teaching strategy to students' achievement in Integrated Science

Martin C. Njoroge (2013) focused on the application of crossword puzzles in the teaching of vocabulary in English as Second Language (ESL) classrooms. Also crossword puzzles considered to teach vocabulary (Widaningsih 2009, ; Moore & Dettlaff, 2005; Whisenand and Dunphy,2010; Rosnelly, 2010; Zunita Widyasari, 2010)

Weisskirch, R. S. (2006) used of instructor-created crossword puzzles as a means of reviewing course material while Vasconcelos, A. C. C. G. et. al.(2015) used crosswords used to complement medical education in a fun way and Sulekha Rao Coticone used crossword puzzles to incorporate active learning in the biochemistry classroom

Rixon suggests that games can be used at all stages of the lesson, provided that they are suitable and carefully chosen. S. M. Silvers said many teachers are enthusiastic about using games as "a teaching device," while Zdybiewska believed games to be a good way of practising language.

Donald L. Williams (2007) suggested the use of educational games such as crossword puzzles, word search puzzles, modified television game shows, or commercial board and card games to make learning more fun and motivational regardless of the level of educational experience.

Aa board game was developed for pediatric medical students to help them retain knowledge gained during third-year clinical clerkships and resident rotations (Ogershok & Cottrell, 2004)

3. Puzzle based Learning (PBL)

Falkner (2009) indicated that students perceive an improvement in their thinking and general problem-solving skills due to puzzle based learning. It increase student engagement and promote independent learning.(M. Badger, c. J. Sangwin). Also puzzle-Based Learning - is very beneficial for introducing mathematics, critical thinking, and problem-solving skills.(Zbigniew Michalewicz, Matthew Michalewicz; Colin Thomas et.)

Puzzle based learning can be used to attract, motivate, and retain students and increase their mathematical awareness and problem-solving skills (Nickolas Falkner, Raja Sooriamurthi, Zbigniew Michalewicz.)

4. Game based Learning (GBL)

Game-based learning is nothing but designing learning activities that can introduce concepts, and improve the problem solving skill of students. Game based learning can increase student motivation, engagement, and student learning. Game-based learning provides an opportunity for instructors to incorporate active learning into their teaching-learning process, promote students' interest and engagement, and provide immediate feedback on performance. (Annie Pho and Amanda Dinscore. Game-Based Learning). GBL introduce teaching with energy, enhance innovative thinking and provide diversity in teaching methods. GBL mainly aims in terms of increasing learning, retention (Kapp, K.M.,2012)

5. Game and Puzzle based Learning (GPBL)

In Game and Puzzle based Learning (GPBL), I combined the Puzzle based and Game based Learning. This GPBL is designed to create interest in the course, attract, motivate and retain the students to enhance the critical thinking and problem solving skill. In GPBL, I considered the game like Snake and Ladder and the following puzzles

- Crossword Puzzle
- Word Search Puzzle
- Word Matching Puzzle
- Word Scramble

Digital Technique course consist of six units as given below

- Combinational Logic Circuit
- Arithmetic Circuit
- Digital Design Circuit
- Digital Circuit with MSI(Medium Scale Integration)
- Memory Organization
- VHDL (VHSIC(Very High Speed Integrated Circuit) Hardware Description Language)

In GPBL activity, puzzles and games were considered one on two units of the course as given below

- Combinational Logic Circuit and Arithmetic Circuit
- Digital Design Circuit and Digital Circuit with MSI(Medium Scale Integration)
- Memory Organization and VHDL (VHSIC(Very High Speed Integrated Circuit) Hardware Description Language)

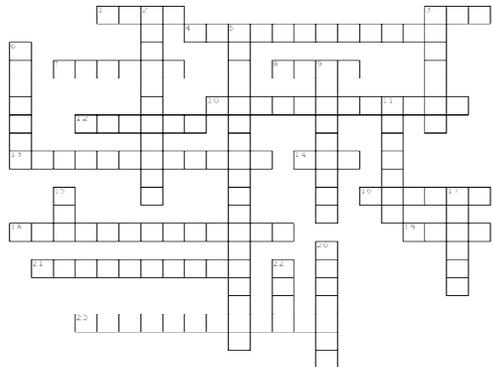
Each puzzle and game is considered for two units of the course. So total twelve puzzles (three crossword puzzle, three word search puzzle, three word matching puzzle and three word scramble) and three snake and ladder games (one for each above topic) are considered as a part of this GPBL activity

Table 4: Rubrics for CO-PO Mapping

Topics→ Puzzles and Games ↓	Combinational Logic Circuit and Arithmetic Circuit	Digital Design Circuit and Digital Circuit with MSI	Memory Organization and VHDL
Crossword Puzzle	1 (20 clues)	1 (22 clues)	1 (25 clues)
Word Search Puzzle	1 (16 words in puzzle)	1 (14 words in puzzle)	1 (25 words in puzzle)
Word Matching Puzzle	1 (10 words in puzzle)	1 (10 words in puzzle)	1 (10 words in puzzle)
Word Scramble	1 (16 words in puzzle)	1 (14 words in puzzle)	1 (20 words in puzzle)
snake and ladder	30 Questions on the topic	30 Questions on the topic	30 Questions on the topic

Digital Technique is shown in Figure 3. This crossword consist of 14 across clues while 10 horizontal clues. The solution to this crossword is given in Figure 4.

Digital Design and Digital Ckt with MSI
Complete the crossword below



Across

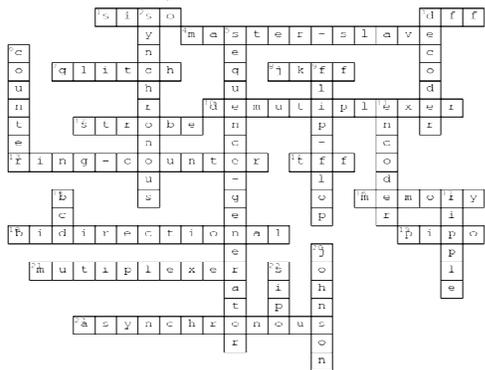
1. serial left shift and right shift
3. delay flip flop
4. cascade of two srrf with feedback from the output of second to the inputs of first
7. problem of asynchronous counter
8. race around condition
10. reverse operation of multiplexer
12. a _____ input is used for cascading purpose in multiplexer
13. injected pulse will keep circulating
14. toggle flip flop
16. a _____ element is some medium in which one bit of information stored
18. register in which data can be shifted in both direction i.e. left or right
19. simultaneous entry of all data bits and parallel output
21. circuit that gets one out of several input to a single output
23. all flip flops are not clocked simultaneously

Down

2. all flip flops are clocked simultaneously
3. circuit that converts n-bit binary input code into m-output lines
5. generation of prescribed sequence of bits in synchronism with clock
6. circuit for counting the pulse
9. basic digital memory circuit
11. circuit which converts digit and/or special symbol to a binary coded format
15. decimal digit 0 to 9 represented by their natural binary equivalent
17. asynchronous counter is also known as
20. twisted ring counter is also known as
22. data entered serially and taken out parallelly

Fig. 3: Crossword example on the topic 'Digital Design and Digital Circuit with MSI'

Digital Design and Digital Ckt with MSI
Complete the crossword below



Across

1. serial left shift and right shift (**siso**)
3. delay flip flop (**dff**)
4. cascade of two srrf with feedback from the output of second to the inputs of first (**master-slave**)
7. problem of asynchronous counter (**glitch**)
8. race around condition (**jkff**)
10. reverse operation of multiplexer (**demultiplexer**)
12. a _____ input is used for cascading purpose in multiplexer (**strobe**)
13. injected pulse will keep circulating (**ring-counter**)
14. toggle flip flop (**tff**)
16. a _____ element is some medium in which one bit of information stored (**memory**)
18. register in which data can be shifted in both direction i.e. left or right (**bidirectional**)
19. simultaneous entry of all data bits and parallel output (**piipo**)
21. circuit that gets one out of several input to a single output (**multiplexer**)
23. all flip flops are not clocked simultaneously (**asynchronous**)

Down

2. all flip flops are clocked simultaneously (**synchronous**)
3. circuit that converts n-bit binary input code into m output lines (**decoder**)
5. generation of prescribed sequence of bits in synchronism with clock (**sequence generator**)
6. circuit for counting the pulse (**counter**)
9. basic digital memory circuit (**flip-flop**)
11. circuit which converts digit and/or special symbol to a binary coded format (**encoder**)
15. decimal digit 0 to 9 represented by their natural binary equivalent (**bcd**)
17. asynchronous counter is also known as (**ripple**)
20. twisted ring counter is also known as (**johnson**)
22. data entered serially and taken out parallelly (**siop**)

Fig. 4: Crossword example solution on the topic 'Digital Design and Digital Circuit with MSI'

C. Word search Puzzle

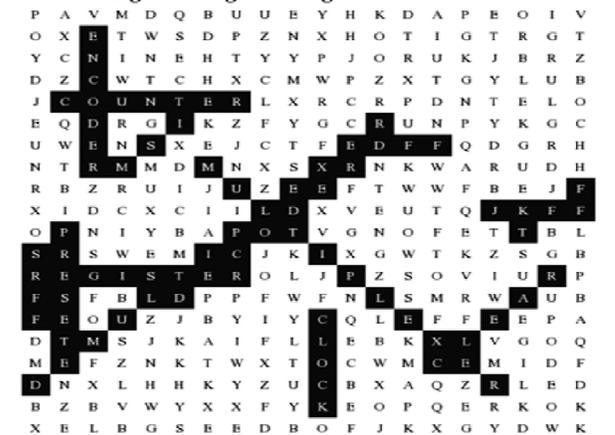
Word search puzzles are generally used to increase the vocabulary. A word search puzzle is a word game that is letters of a word in a grid that usually has a rectangular or square shape and the search for the word is either vertically, or horizontally or diagonally. The objective of this puzzle is to find and mark all the words hidden inside the box (Ria Damayanti H., 2014). The sample word search puzzle on the topic 'Digital Design and Digital Circuit with MSI' of the course Digital Technique is shown in Figure 5. This word search puzzle consists of 14 hidden words.

Digital Design and Digital Ckt with MSI



Fig. 5: Word Search example on the topic 'Digital Design and Digital Circuit with MSI'

Digital Design and Digital Ckt with MSI



SRFF	JKFF	dff
TFF	REGISTER	COUNTER
CLOCK	PRESET	CLEAR
MULTIPLEXER	DEMULTIPLEXER	ENCODER
DECODER	MSI	

Fig. 6: Word Search example solution on the topic 'Digital Design and Digital Circuit with MSI'

The solution to this word search example is given in Figure 6. Using this puzzle, students try to memorize the term they learned in this unit of the course.

D. Word Matching Puzzle

The Word Matching puzzle is one where the user has to match a word or phrase to its corresponding phrase. The sample word matching puzzle on the topic 'Digital Design and Digital Circuit with MSI' of the course Digital Technique is shown in Figure 7. This word matching puzzle consists of 10 words and phrases. The solution to this word matching puzzle example is given in Figure 8.

Digital Design and Digital Ckt with MSI		
Write the letter of the correct match next to each problem.		
1. _____	synchronous	a. all flip flops are not clocked simultaneously
2. _____	counter	b. all flip flops are clocked simultaneously
3. _____	twisted ring counter	c. circuit that convert the n-bit binary input code into m-output lines
4. _____	ring counter	d. output Q of last flip flop is connected to the input of first flip flop
5. _____	ripple	e. decimal digit 0 to 9 represented by their natural binary equivalent
6. _____	race around condition	f. input used for cascading purpose in multiplexer
7. _____	decoder	g. JK flip flop
8. _____	BCD	h. circuit for counting the pulse
9. _____	strobe	i. output Q of last flip flop is connected to the input of first flip flop
10. _____	sequence generator	j. generation of prescribed sequence of bits in synchronism with clock

Fig. 7: Word matching example on the topic 'Digital Design and Digital Circuit with MSI'

Digital Design and Digital Ckt with MSI		
Write the letter of the correct match next to each problem.		
1. <u>b</u> _____	synchronous	a. all flip flops are not clocked simultaneously
2. <u>h</u> _____	counter	b. all flip flops are clocked simultaneously
3. <u>i</u> _____	twisted ring counter	c. circuit that convert the n-bit binary input code into m-output lines
4. <u>d</u> _____	ring counter	d. output Q of last flip flop is connected to the input of first flip flop
5. <u>a</u> _____	ripple	e. decimal digit 0 to 9 represented by their natural binary equivalent
6. <u>g</u> _____	race around condition	f. input used for cascading purpose in multiplexer
7. <u>c</u> _____	decoder	g. JK flip flop
8. <u>e</u> _____	BCD	h. circuit for counting the pulse
9. <u>f</u> _____	strobe	i. output Q of last flip flop is connected to the input of first flip flop
10. <u>j</u> _____	sequence generator	j. generation of prescribed sequence of bits in synchronism with clock

Fig. 8: Word matching example solution on the topic 'Digital Design and Digital Circuit with MSI'

E. Word Scramble

Word scramble puzzle is a word puzzle with a set of words, each of which is "jumbled" by scrambling its letters. Students construct the words, and then arrange letters in the words to spell the answer. The sample word scramble puzzle on the topic 'Digital Design and Digital Circuit with MSI' of the course Digital Technique is shown in Figure 9. This word scramble puzzle consists of 15 hidden words. The solution to this word scramble example is given in Figure 10.

Digital Design and Digital Ckt with MSI

Please unscramble the words below

1. rfsf

2. fjfk

3. ffd

4. ftf

5. ersreigt

6. otrnuec

7. ccklo

8. steper

9. lcrea

10. mitrlxelpuc

11. miedrtelxlepu

12. credeno

13. decrdoe

14. ims

Fig. 9: Word scramble example on the topic 'Digital Design and Digital Circuit with MSI'

Digital Design and Digital Ckt with MSI

Please unscramble the words below

1. rfsf	sfff
2. fjfk	jkff
3. ffd	dff
4. ftf	tff
5. ersreigt	register
6. otmucc	counter
7. ccklo	clock
8. steper	preset
9. lcrea	clear
10. mitrlxelpue	multiplexer
11. miedrtelxlepu	demultiplexer
12. credeno	encoder
13. decrdoe	decoder
14. ims	msi

Fig. 10: Word matching example solution on the topic 'Digital Design and Digital Circuit with MSI'**F. GPBL Material on Webpage and Slideshare.net**

The crossword puzzles, word search puzzles, word scramble puzzles and word matching puzzles are also available on my webpage

<https://sunitadolwit.wordpress.com/study-material/digital-technique-2/puzzles-and-games/crossword-puzzle/>

<https://sunitadolwit.wordpress.com/study-material/digital-technique-2/puzzles-and-games/word-search-puzzle/>

<https://sunitadolwit.wordpress.com/study-material/digital-technique-2/puzzles-and-games/word-scramble/>

<https://sunitadolwit.wordpress.com/study-material/digital-technique-2/puzzles-and-games/word-matching-puzzle/>

or on the slideshare.net and the links for crossword puzzles are

<http://www.slideshare.net/SunitaAher1/combination-al-logic-and-arithmetic-circuit-crossword-puzzle>

<http://www.slideshare.net/SunitaAher1/digital-design-and-digital-circuit-with-msi-crossword-puzzle>

<http://www.slideshare.net/SunitaAher1/memory-organization-and-vhdl-crossword-puzzle>

The links for word search puzzles are

<http://www.slideshare.net/SunitaAher1/combination-al-logic-and-arithmetic-circuit-word-search-puzzle>

<http://www.slideshare.net/SunitaAher1/digital-design-and-digital-circuit-with-msi-word-search-puzzle>

<http://www.slideshare.net/SunitaAher1/memory-organization-and-vhdl-word-search-puzzle>

The links for word matching puzzles are

<http://www.slideshare.net/SunitaAher1/combination-al-logic-and-arithmetic-circuit-word-matching-puzzle>

<http://www.slideshare.net/SunitaAher1/digital-design-and-digital-circuit-with-msi-word-matching-puzzle>

<http://www.slideshare.net/SunitaAher1/memory-organization-and-vhdl-word-matching-puzzle>

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<http://www.slideshare.net/SunitaAher1/digital-design-and-digital-circuit-with-msi-word-scramble-puzzle>

<http://www.slideshare.net/SunitaAher1/memory-organization-and-vhdl-word-scramble>

G. Feedback about GPBL

To know students' perception about this activity, feedback was conducted at the end of this activity as shown in Table 2. From the table 100% students agreed that they liked this activity.

Table 2: Feedback about GPBL activity

Sr. No.		Strongly Agree	Agree	Disagree	Strongly Disagree
1	Game and Puzzle based learning helped to enhance my knowledge of Digital Technique.	55%	38%	6%	0%
2	Game and Puzzle based learning helped me to retain the content of the subject.	49%	51%	0%	0%
3	Because of this activity, I recalled the terms related to the topics of the course Digital Technique.	68%	30%	0%	2%
4	Whether this activity was entertaining to boost my knowledge.	70%	28%	2%	0%
5	I enjoyed this activity and fun experienced to solve the puzzles and play the game.	72%	28%	0%	0%
6	Word Search and Word scramble puzzle helped me to recall remember the terms taught in this subject.	55%	43%	2%	0%
7	Cross word puzzle was challenging and improved my understanding of the units of this course.	47%	47%	6%	0%
8	Word match puzzle helped me to revise the concepts.	49%	47%	4%	0%
9	Game helped to interact with the team member and thus cleared the concept about the topic.	45%	53%	0%	2%
10	Group discussion in the game was very useful.	45%	52%	2%	2%
11	Game and Puzzle based learning activity is useful to build the terms related to the course	62%	36%	2%	0%
12	Did you like this activity? Any comment.	Yes=100%			

6. Advantages of GPBL

Following are the advantages of GPBL to the students

- Improve critical thinking
- Improve problem solving ability
- Improves the conceptual understanding about the course
- Increase students' motivation and engagement
- Enhance thinking ability
- Attract and retain students and
- Group discussion
- Enables the students to think in divergent directions to generate more points
- Enhances the peer learning.
- Gain more knowledge by getting others opinion
- Encourages learners to exchanges their own experiences, thereby making learning more active
- Attain deeper understanding of topics

7. Conclusions

In this study, Game and Puzzle based Learning (GPBL) where I combined two active learning strategies Puzzle based Learning (PBL) and Game based Learning (GBL) is considered. the game considered in Game based Learning was Snake So I consider Crossword puzzle, word search puzzle, word scramble puzzle and word match puzzle in Puzzle based Learning and Ladder game. From the feedback, it is found that 100% students liked this activity. This activity helped to engage the students and make the learning more effective. This activity also helped to improve critical thinking and problem solving skills of the students.

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