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An Effective Way to Improve Problem Solving Skill using TPS, T24S and T21S: A Comparative Study

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Abstract: While studying various engineering courses, we often come across two types of problem statements: Simple problems which are possible to solve within two steps whereas Complex one are those which required more than two steps to solve. Further in complex type of problem statement, there are two types: Type 1- Complexity is less initially and increases as we proceed further and Type 2- Complexity is more initially and it decreases for further steps. In the present study, we considered the active learning strategies to solve these types of problem statement. For this study, Theory of Computation course of Second Year Computer Science and Engineering is considered.

Think-Pair-Share (TPS) is a well known active learning strategy in which students work on a problem posed by instructor, first individually (Think), then in pairs (Pair) and finally together with the entire class (Share). TPS is considered for Simple type of problem statement.

After implementing TPS frequently, we have modified the TPS activity in such a way that it can be used to solve the Type1 and Type2 problem statements as mentioned above. The modified active learning strategies are renamed T24S (Think-Pair-Four in Group-Share) and T21S (Team-Pair-Individual-Share). T24S consist of four phases- Think, Pair, Four in group and Share phase. In phase "four in group phase", two pair work together to complete the task. So this T24S activity is considered to solve the Type1 examples.

In T21S, students work in the group of four to solve the problem statement. Next, teams split into pair to work on the same problem statement. Finally pair breaks up and student work individually to complete the task followed by sharing of the problem statement solution with the class. Such T21S activity is employed for solving the Type 2 problem statements.

We conducted pre-post single group study for three learning objectives (LOs) as (1) solve the simple problem statement (LO1), (2) solve the complex problem statement of Type1 (LO2) and (3) solve the complex problem statement of Type2 (LO3). It is found that TPS, T24S and T21S methods are useful for satisfying LO1, LO2 and LO3 respectively. The objective of this study is to improve the problem solving skill of students.

In this study, we are presenting the results obtained along with feedback about TPS, T24S and T21S.

Keywords: TPS (Think-Pair-Share), T24S (Think-Pair-Four in the group-Share), T21S (Team-Pair-Individual-Share), t-Test, Likerts' Scale, Theory of Computation.

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1. Introduction

In Engineering and Technology programs, various courses studied are generally classified into the following categories:

- Applied Mathematical Courses e.g. Applied Mathematics
- Algorithm based courses e.g. System Programming
- Logical courses e.g. Theory of Computation

Many courses contain the complex problems. Generally, students find such complex problems difficult to learn and understand. Therefore, with a view to make these course interesting, active learning strategies need to be incorporated in teaching-learning process.

Active learning strategies include a wide range of activities that share the common element of —involving students in doing things and thinking about the things they are doing (Bonwell & Eison 1991). Michael Prince (2004) examined the evidence for the effectiveness of active learning. Generally, students' concentration during lectures decline after 10-15 minutes (Stuart & Rutherford, 1978). Active learning 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). When students are actively involved in the learning task, they learn more (Cross, P., 1987). Active learning instructional strategies may not be used due to the large class size, but the authors (Heppner, 2007; Stanley & Porter, 2002; Weimer, 1987) offer the ideas on how to teach large classes. TPS is a suitable strategy to use in the large class (Aditi Kothiyal et. al., 2013).

In this paper, we presented the result along with feedback about TPS, T24S and T21S.

2. Related Work

There are various active learning strategies for teaching this course Theory of Computation. Some of these strategies are discussed in this section.

There are software tools freely available via the Internet (Carlos I. Ches˜nevar et al., 2003) and Intelligent Tutoring System (ITS) called FLUTE (V. Devedzic et. al., 2000) for teaching formal languages and automata theory. Also the authors (Anna O. Bilska et. Al, 1997) developed a collection of instructional tools for experimenting with automata, grammars and parsing for the formal languages course.

A number of didactic strategies based on a constructivist approach like use of simulators, relating subject to Programming Language, presenting and discussing the technical article related to the application of the subject and a stronger use of technology, etc. (Carlos I. Ches˜nevar et al., 2004) and integrating this course with other courses learnt in previous semesters and current semester of engineering like Programming Language, Data Structure, etc (Mukta Goyal and Shelly Sachdeva, 2009) were considered for Theory of Computation.

The authors (S. H. Rodger et. al., 2006) pointed out the difficulty to teach formal languages and automata on traditional approaches and presented a hands-on approach to problem solving in the formal languages and automata theory course.

Activity oriented teaching learning was attempted in the course and a tutorial was introduced for this course with an objective of increasing student participation (Vijayalaskhmi, M., 2012).

Think-Pair-Share active learning strategy is useful technique because of its benefits of allowing students to express their reasoning, reflect on their thinking, and obtain immediate feedback on their understanding (Aditi Kothiyal et. al., 2013). This activity is useful for the courses like Theory of Computation (Sunita M Dol 2014), Operating System (Komal R. Pardeshi, 2016). The modified TPS activities like T24S (Dr. S. A. Halkude and Sunita M. Dol, 2016) and TPFOSSS (Dr. S. A. Halkude and Sunita M. Dol, 2015) are also useful for Theory of Computation. TPFOSSS activity which is employed only to those courses for which free open source simulation softwares are available is also useful for teaching Compiler Construction course (Sunita B. Aher and Dattatray P Gandhmal, 2014).

The authors (San Tint and Ei Nyunt, 2015) designed a model for Java Programming learning system that facilitates the collaborative learning activities TPS in a virtual classroom. The paper (N. A.

Nik Azlina, 2010) introduced a collaborative framework for CETLs which adapt the use of Think-Pair-Share in a collaborative environment. TPS was also conducted to improve students' English speaking ability (Abdurrahman Hi. Usman, 2015). Even the study (Sampsel, Ariana, 2013) addressed the Think-Pair-Share cooperative learning technique and its effects on students' confidence in their abilities to do mathematics and their willingness to participate in class discussion.

3. Methodology

A. Sample

Since this study was considered for mathematical course like Theory of Computation of Second Year Computer Science and Engineering, so a group of 40 students from second year is considered. This is one group pre-post test method.

B. TPS

Think Pair Share is a well known active learning strategy in which students work on a problem posed by instructor, first individually (Think), then in pairs (Pair) and finally together with the entire class (Share) (Gargi Banerjee et.al , 2013). The research (Carss and Wendy Diane, 2007) described the effects of Think-Pair-Share strategies on reading achievement.

This activity develops soft skills, promotes confidence, self learning & critical thinking ability. So this TPS consist of three phases, Think, Pair and Share (Susan Ledlow, 2001 and http://www.hydroville.org/system/files/team_thinkpairshare.pdf)

Here, we considered the problem statement from Theory of Computation course - Write the context free grammar for given regular expression. The steps are shown for this problem statement in the following Fig. 1.

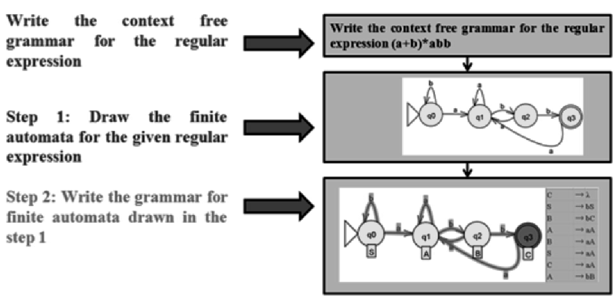

Fig. 1: Problem statement for Think-Pair-Share Activity

How to solve this problem statement using TPS activity is shown in the Fig. 2.

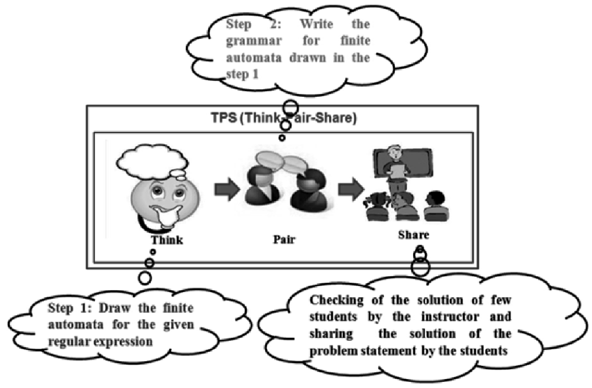

Fig. 2: Solving the problem statement using Think-Pair-Share Activity

C.T24S

Since TPS consist of three phases- Think, Pair and Share, for some complex examples, working in pairs is not sufficient to solve the problems. So there is a burden either on Think phase or Pair phase. Therefore, more than two students in a group are required to attempt and solve the problem. The TPS method is modified and one more phase is added to it. The modified TPS is titled as T24S. T24S consist of four phases- Think, Pair, Four in group and Share phase. In phase "four in group phase", two pair work together to complete the task. T24S activity is shown in the Fig. 3.

The 'four in group' phase in the T24S activity works best for problem solving strategies and/or complicated case studies.

This technique is used to get students to use higher level thinking and justify their reasoning.

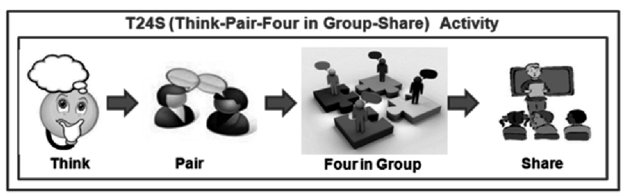

Fig. 3: Think-Pair-Four in group-Share Activity

Topic considered from the course 'Theory of Computation' for T24S is: Simplified forms and normal forms

Problem statement: converting the given context free grammar to Chomsky Normal Form which consist of four steps as shown in the following Fig. 4.

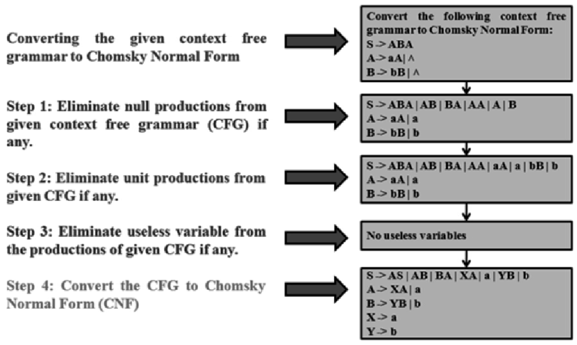

Fig. 4: Problem statement for Think-Pair-Four in group-Share Activity

So in T24S activity, step 1 is considered in Think phase, step 2 and 3 in Pair phase (as there may not be any useless variables in the step 3) while step 4 is considered in 'four in group' phase followed by Share phase. Solving the problem statement using T24S is

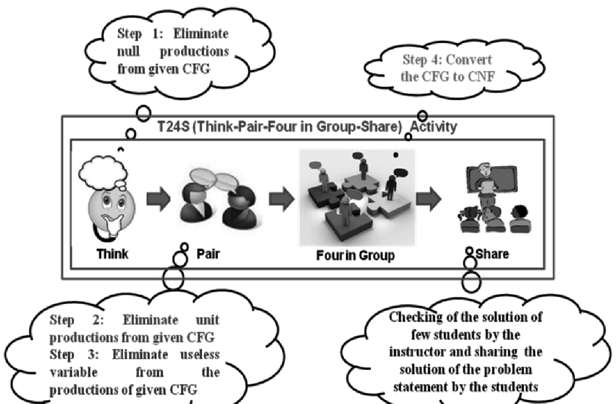

Fig. 5: Solving the problem statement using Think-Pair-Four in group-Share Activity

shown in the Fig. 5.

D.T21S

T21S activity consists of four steps: Team, Pair, Individual and Share. In T21S, students work in the group of four to solve the problem statement. Next, teams break into pairs to work on the same problem statement. Finally, pair breaks up and students work individually to complete the task followed by sharing of the problem statement solution with the class. The activity T21S works well for problems and concepts that students would either be too intimidated or just incapable of doing on their own.

Using T21S, students can often progress to working individually on problem statement that they wouldn't have been able to complete without using this cooperative learning activity. T21S activity is shown in Fig. 6.

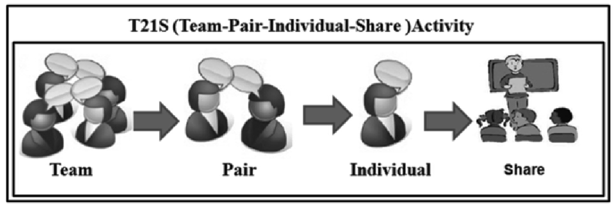

Fig. 6: Team-Pair-Individual-Share Activity

For T21S activity, the topic from the course Theory of Computation is – Conversion of Nondeterministic Finite Automata with null (NFA-Λ) to Deterministic Finite Automata (DFA) that is conversion of NFA with null to DFA.

Problem statement: Converting the given NFA-Λ to DFA which consist of four steps is shown in Fig. 7.

In this problem statement, step 1 requires more than two students to solve the problem and the complexity decreases from step 2 to step 4.

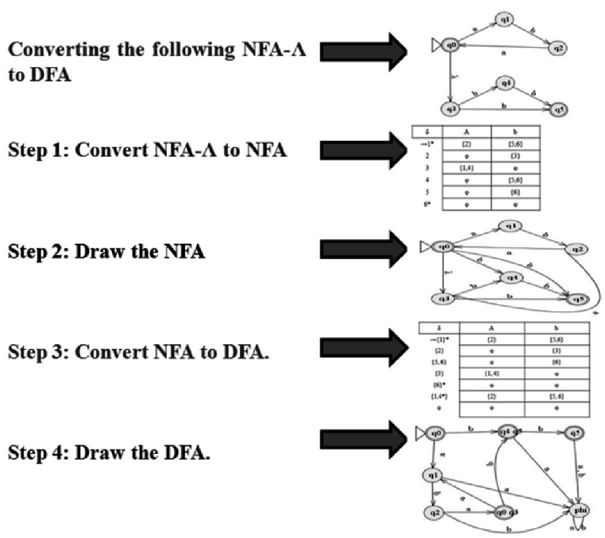

Fig. 7: Problem statement for Team-Pair-Individual-Share Activity

Now how to solve the problem statement is shown in Fig. 8 using T21S activity. Step 1 is considered in Team phase, step 2 and 3 in Pair phase while step 4 is considered in individual phase followed by Share phase.

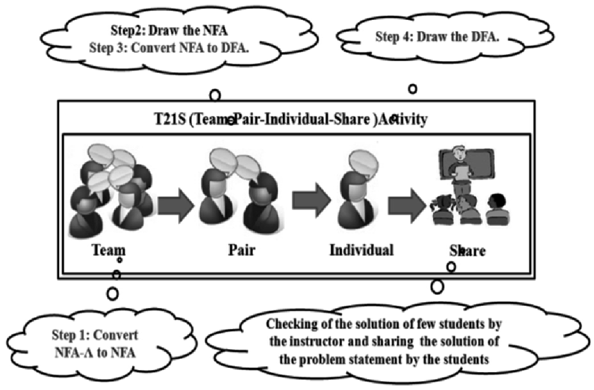

Fig. 8: Solving the problem statement using Team-Pair-Individual-Share Activity

4. Experimental Detail

A. Research Design for TPS, T24S and T21S

For all three activities TPS, T24S and T21S, one group pre-post method is considered. In all these three activities, first the students were taught corresponding topic using traditional method that is blackboard teaching. We conducted the pre-test for these three topics. After this test, instructor conducted the first topic using TPS, second topic using T24S and third topic using T21S activity. The students were given post-test with similar types of the problems with different applications on these three topics.

The research design using for TPS, T24S and T21S activity is given in Fig. 9.

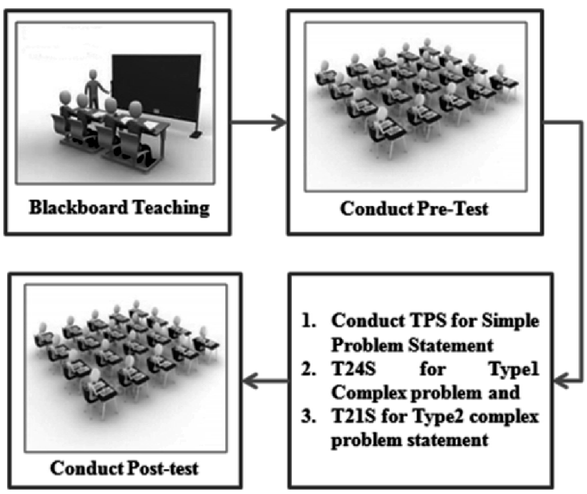

Fig. 9: Research design for TPS, T24S and T21S

B. Learning Objectives (LOs), Research Question (RQ) and Hypothesis of the Study

Learning Objectives (LOs) of this study is to teach problem solving skill. These LOs are:

- To solve the simple problem statement (LO1)
- To solve the complex problem statement of Type1 - Complexity is less initially and it increases as the number of steps increases (LO2)
- To solve the complex problem statement of Type2 - Complexity is more initially and it decreases as the number of steps increases (LO3)

All examples considered in each LO are from the course Theory of Computation of Second Year Computer Science and Engineering

Our research question (RQ) was

RQ: What is the difference between pre and post-test scores of the students for the problem solving after TPS, T24S and T21S?

Hypothesis of our study is

H1: Students' post test scores for LO1 are higher than pre-test score after teaching using TPS.

H2: Students' post test scores for LO2 are higher than pre-test score after teaching using T24S.

H3: Students' post test scores for LO3 are higher than pre-test score after teaching using T21S.

C. Pre and Post-Test Questions

Pre-Test and Post-Test were conducted on the following three topics:

1. Write the context free grammar for given regular expression
2. Conversion of the given context free grammar to Chomsky Normal Form.
3. Conversion of Nondeterministic Finite Automata with null (NFA-Λ) to Deterministic Finite Automata (DFA)

The weightage of test 1was 25 marks while test 2 and test 3 was 30 marks.

Bloom's taxonomy is a set of three hierarchical models used to classify educational learning objectives into levels of complexity and mastery (https://en.wikipedia.org/wiki/Bloom%27s_taxonomy).

These questions cover Apply and Analyse level of Bloom's Taxonomy. The sample question for test 1, test 2 and test 3 is shown in the Fig. 10a, Fig. 10b and Fig. 10c of Fig. 10 respectively.

Write the context free grammar for the regular expression (a+b)*abb

Fig. 10a: Test question for TPS

Convert the following context free grammar to Chomsky Normal Form:
S -> ABA
A-> aA| Λ
B -> bB | Λ

Fig. 10b: Test question for T24S

Converting the following NFA-Λ to DFA

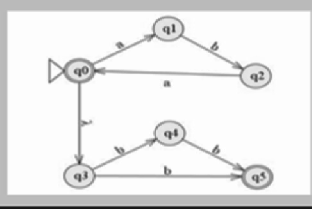

Fig. 10c: Test question for T21S
Fig. 10: Test question for TPS, T24S and T21S

D. Feedback

To understand students' perception about TPS, T24S and T21S activity, the feedback was conducted at the end of each activity. The feedback about TPS, T24S and T21S is shown in the Table 1, Table 2 and Table 3 respectively. It is found that

- 100% students liked TPS activity,
- 100% students liked T24S activity and
- 97% students liked T21S activity.

Table1: Feedback about TPS activity

		Never	Sometimes	Often	Always
1	How frequently did you write the solution to the problem given by the instructor during the think phase?	3%	19%	26%	52%
2	How frequently did you discuss your solution with your partner during the pair phase?	5%	17%	22%	57%
		SD	**D**	**A**	**SA**
3	I stayed interested in the content of the lecture because of the think-pair-share activities.	2%	1%	72%	25%
4	Thinking about the problem and writing the solution during the think phase helped me learn <topic> concepts.	0%	5%	61%	36%
5	Discussing my solution with my partner during the pair phase helped me learn <topic> concepts	3%	4%	48%	45%
6	Listening to other students' solutions and discussion during the share phase helped me learn <topic> concepts.	3%	4%	43%	50%
7	I would not have learned as much from the lecture if there had been no think-pair-share Scale activities.	5%	27%	50%	18%
8	Did you like the Think-Pair–Share activity: Yes/No Why?	TPS Yes=100%			

Table 2: Feedback about T24S activity

		Never	Sometimes	Often	Always
1	How frequently did you write the solution to the problem given by the instructor during the think phase?	3%	25%	34%	37%
2	How frequently did you discuss your solution with your partner during the pair phase?	2%	15%	22%	57%
3	How frequently did you discuss your solution with your partner during the four in group phase?	2%	22%	25%	52%
		SD	**D**	**A**	**SA**
4	I stayed interested in the content of the lecture because of the T24S	2%	9%	63%	26%
5	Thinking about the problem and writing the solution during the think phase helped me learn <topic> concepts.	0%	9%	66%	25%
6	Discussing my solution with my partner during the pair phase helped me learn <topic> concepts	0%	8%	40%	52%
7	Discussing my solution with my partner during the four in group phase helped me learn <topic> concepts	0%	6%	38%	55%
8	Listening to other students' solutions and discussion during the share phase helped me learn <topic> concepts.	2%	8%	62%	28%
9	I would not have learned as much from the lecture if there had been no T24S.	2%	35%	52%	11%
10	Did you like this T24S activity(Yes/No)? Why?	T24S Yes=100%			

Table 3: Feedback about T21S activity

		Never	Sometimes	Often	Always
1	How frequently did you discuss your solution with your partner during team phase?	2%	25 %	30 %	43%
2	How frequently did you discuss your solution with your partner during the pair phase?	3%	23 %	25 %	48%
3	How frequently did you write the solution to the problem given by the instructor during the individual phase?	0%	25 %	28 %	47%
		SD	**D**	**A**	**SA**
4	I stayed interested in the content of the lecture because of the TPSS activity.	3%	2%	75 %	20%
5	Discussing my solution with my partner during the team phase helped me learn <topic> concepts	2%	0%	57 %	42%
6	Discussing my solution with my partner during the pair phase helped me learn <topic> concepts	2%	0%	55 %	43%
7	Thinking about the problem and writing the solution during the individual phase helped me learn <topic> concepts.	2%	10 %	50 %	38%
8	Listening to other students' solutions and discussion during the share phase helped me learn <topic> concepts.	7%	2%	57 %	35%
9	I have learned much about the topic from TPSS activity and this activity clears doubt about topic.	2%	2%	52 %	45%
10	Did you like T21S (yes/no) and why?	T21S=97%			

In above three table, SD-Strongly Disagree, D-Disagree, A-Agree and SA-Strongly Agree.

5. Results

Students' problem solving skill was analysed using pre-test and post-test marks. Test result is shown in Fig. 11a for TPS activity, Fig. 11b for T24S activity and Fig. 11c for T21S activity of Fig. 11. Graph in Fig. 11a, 11b and 11c shows that students performed better in post-test as compared to pre-test.

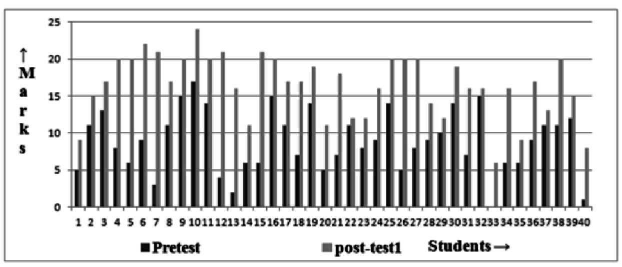

Fig. 11a: Performance of Students in pre-test, post-test for TPS activity in Theory of Computation

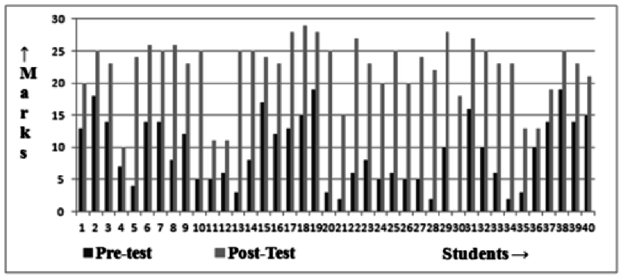

Fig. 11b: Performance of Students in pre-test, post-test for T24S activity in Theory of Computation

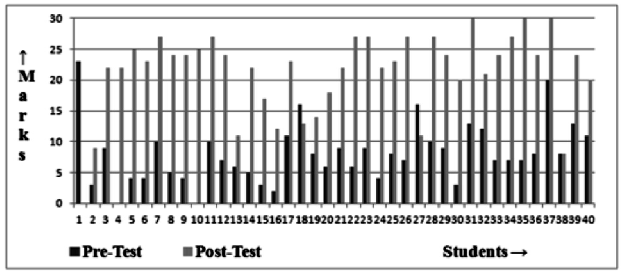

Fig. 11c: Performance of Students in pre-test, post-test for T21S activity in Theory of Computation

Fig. 11: Performance of Students in pre-test, post-test for TPS, T24S and T21S activity in Theory of Computation

Statistical analysis using t-Test and Mann-Whitney Test is performed for pre-post test of TPS, T24S and T21S activity. t-test is used to determine if two sets of data are significantly different from each other. For t-test to be significant statically, t must be at least 2.145 and $p<=0.05$. t-Test result also shows statistical significant difference between pre and post-test result of students' performance using TPS, T24S and T21S activity.

Table 4: Statistical Analysis using t-Test Result for pre-test and post-test of TPS, T24S and T21S activity

Degree of Freedom	Standard Deviation	t value	p value
	TPS		
78	4.23	7.98	<0.0001
	T24S		
124	5.22	12.5	<0.0001
	T21S		
76	5.16	12.1	<0.0001

We have performed the statistical analysis using Mann-Whitney test using IBM's SPSS tool (https://www-01.ibm.com/marketing/iwm/iwmdocs/tnd/data/web/en_US/trialprograms/W110742E06714B29.html). This test is used to compare two population means which come from the same population.

Statistical Analysis using Mann-Whitney Test is done for pre-test and post-test of TPS. Table 5 indicates that data has non-normal distribution. Hence, the non-parametric Mann-Whitney test is

Table 5: Normality Test for pre-test and post-test of TPS

Tests of Normality							
		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistic	df	Sig.
Pre-Test	1.00	.101	40	.020*	.972	40	.041
Post-Test	2.00	.148	40	.027	.941	40	.038

Table 6: Mann-Whitney Test for pre-test and post-test of TPS

Test Statistics[a]	
	testMarks
Mann-Whitney U	157.500
Wilcoxon W	977.500
Z	-6.195
Asymp. Sig. (2-tailed)	.000

Table 7: Normality Test for pre-test and post-test of T24S

Tests of Normality							
		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	group	Statistic	df	Sig.	Statistic	df	Sig.
Pre-Test	1.00	.149	40	.025	.945	40	.051
Post-Test	2.00	.235	40	.000	.864	40	.000

Table 8: Mann-Whitney Test for pre-test and post-test of T24S

Test Statistics[a]	
	testMarks
Mann-Whitney U	85.000
Wilcoxon W	905.000
Z	-6.892
Asymp. Sig. (2-tailed)	.000

Table 9: Normality Test for pre-test and post-test of T21S

Tests of Normality							
		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	group	Statistic	df	Sig.	Statistic	df	Sig.
testMarks	1.00	.099	40	.020*	.969	40	.032
	2.00	.205	40	.000	.891	40	.001

Table 10: Mann-Whitney Test for pre-test and post-test of T21S

Test Statistics[a]	
	testMarks
Mann-Whitney U	61.500
Wilcoxon W	881.500
Z	-7.118
Asymp. Sig. (2-tailed)	.000

for Simple type of problem statement satisfying LO1.

- T24S, the modified TPS activity is used for solving the Type 1 of Complex problem statement satisfying LO2 while

- T21S strategy is used to attempt and solve the complex problem statement of Type 2 satisfying LO3.

These strategies can be applied to any engineering course which consists of these types of problem statements.

References

Sunita M Dol and Dr. S. A. Halkude (2016) T24S: Modified TPS Activity for Mathematical Course to Improve Students' Fundamental Knowledge, in Journal of Engineering Education and Transformation

Komal R. Pardeshi (2016) Improving the Student Performance Using Think-Pair-Share for Operating System, Journal of Engineering Education and Transformation,DOI:10.16920/jeet/2016/v0i0/85651

Dr. S. A. Halkude and Sunita M. Dol (2015) An Active Learning Strategy Think-PairFree Open Source Software-Share to Teach Engineering Courses, Journal of Engineering Education Transformation, ISSN 2349-2473 (Print), eISSN 2394-1707 (Online), 413-418

Abdurrahman Hi. Usman (2015) Using the Think-Pair-Share Strategy to Improve Students' Speaking Ability at Stain Ternate, Journal of Education and Practice www.iiste.org ISSN 2222-1735 (Paper)

ISSN 2222-288X (Online) Vol.6, No.10, 2015

San San Tint and Ei Ei Nyunt(2015), Collaborative Learning With Think -Pair - Share Technique, Computer Applications: An International Journal (CAIJ), Vol.2, No.1, February 2015

Sunita B. Aher and Dattatray P Gandhmal (2014) TPFOSSS: A Modified TPS Technique to Improve Student's Conceptual understanding of Compiler Construction Course, T4E-2014

Sunita M Dol (2014) TPS(Think-Pair-Share) : An Active Learning Strategy to Teach Theory of Computation Course, International Journal of Educational Research and Technology P-ISSN 0976-4089; E-ISSN 2277-1557, IJERT: 5 [4], 62-67

Sampsel, Ariana (2013) Finding the Effects of Think-Pair-Share on Student Confidence and Participation, Honors Projects. Paper 28

Aditi Kothiyal et. al. (2013) Effect of Think-Pair-Share in a Large CS1 Class: 83% Sustained Engagement, ICER'13, http://www.it.iitb.ac.in/~sri/papers/tps-icer2013.pdf.

Gargi Banerjee et.al. (2013) Teaching with visualizations in classroom setting: Mapping Instructional Strategies to Instructional Objectives, IEEE Fifth International Conference on Technology for Education, 176-183

Vijayalaskhmi, M.(2012) Activity based teaching learning in formal languages and automata theory - An experience, http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=6306722&abstractAccess=no&userType=ins

N. A. Nik Azlina(2010) CETLs : Supporting Collaborative Activities Among Students and Teachers Through the Use of ThinkPair-Share Techniques, IJCSI International Journal of Computer Science Issues, Vol. 7, Issue 5, September 2010 18 ISSN (Online): 1694-0814

Jim Eison (2010) Using Active Learning Instructional Strategies to Create Excitement and Enhance Learning, accessed from https://www.cte.cornell.edu/documents/presentations/Eisen-Handout.pdf on 25-08-2016

Mukta Goyal and Shelly Sachdeva (2009) Enhancing Theory of Computation Teaching through Integration with other Courses, International Journal of Recent Trends in Engineering, 1(2), 137-140.

Carss and Wendy Diane (2007) The Effects of using Think-Pair-Share during Guided Reading Lessons, The University of Waikato.

Heppner, F. (2007). Teaching the large college class: A guidebook for instructors with multitudes. ISBN-13: 978-0470180846 ISBN-10: 0470180846

S. H. Rodger, et. Al. (2006) Turning automata theory into a handson course, In Thirty-seventh SIGCSE Technical Symposium on Computer Science Education, pages 379–383.

Carlos I. Ches˜nevar et al. (2004) Didactic Strategies for Promoting Significant Learning in Formal Languages and Automata Theory, ACM 1581138369, ITiCSE'04, Proceedings of the 9th annual SIGCSE conference on Innovation and technology in computer science education, 7-11.

Michael Prince (2004) Does Active Learning Work? A Review of the Research, Journal of Engineering Education

Carlos Iv´an Ches˜nevar et al. (2004) Teaching Fundamentals of Computing Theory: A Constructivist Approach, Journal of Computer Science & Technology, 4(2), 91-97.

John C. Martin (2003) - Introduction to languages & theory of Computation - (MGH).

Carlos I. Ches˜nevar et al. (2003) Using Theorotical Computer Simulators for Formal Laguages and Automata Theory, ACM SIGCSE Bulletin Homepage archive, 35(2), 33-37.

Stanley, C. A. & Porter, M. E. (2002). Engaging large classes: Strategies and techniques for college faculty.

Susan Ledlow (2001) Using Think-Pair-Share in the College Classroom

V. Devedzic, et. Al.(2000) Teaching formal languages by an intelligent tutoring system , Educational Technology and Society, 3(2), ISSN 1436-4522 .

Anna O. Bilska et al. (1997) A Collection of Tools for Making Automata Theory and Formal Languages Come Alive

Bonwell, C., & Eison, J. (1991). Active learning: Creating excitement in the classroom (ASHE-ERIC Higher Education Report No. 1). Washington, DC: George Washington University. Abstract online at http://www.ed.gov/databases/ERIC_Digests/ed340272.html

Cross, P. (1987). Teaching for learning. AAHE Bulletin, 39(8), 3-7

Weimer, M. G. (Ed.). (1987). Teaching large classes well. New Directions for Teaching and Learning.

Bruner, J. S. (1983). In search of mind: Essays in Autobiography. New York: Harper & Row

Stuart, J. & Rutherford, R. J. (1978). Medical student concentration during lectures. The Lancet, 514- 516.

http://www.hydroville.org/system/files/team_thinkpairshare.pdf

https://en.wikipedia.org/wiki/Bloom%27s_taxonomy

https://www-01.ibm.com/marketing/iwm/iwmdocs/tnd/data/web/en_US/trialprograms/W110742E06714B29.html