T24S : Modified TPS Activity for Mathematical Courses to Improve Students' Fundamental Knowledge

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Abstract: Think-Pair-Share (TPS) is a Collaborative, active learning strategy, in which students work on a problem given by an instructor, initially individually, then in pairs, and finally together with the entire class. T24S is a modified TPS activity in which students initially think individually, followed by discussion on problem-solving strategies in pairs and then in groups of four students followed by share phase. This T24S method is useful for Mathematical based courses like Theory of Computation, mathematics, Earthquake Engineering etc. In this paper, the case study of mathematical course like Theory of Computation course of Computer Science and Engineering is considered. Theory of Computation is the course having mathematical orientation and the prerequisite for many courses in Computer Science and Engineering such as System Programming, Compiler Construction etc. This modified TPS activity is considered for Theory of Computation course to improve students' fundamental knowledge of the course and in turn to improve their performance of students in the examination. In this paper, one group Pre-Test Post-Test model is considered. Experimental results and student's perception about this activity are also presented. Also other active learning strategies considered for this course are explained to improve university results.

Keywords: Think-Pair-Share(TPS), T24S(Think-Pair-Four in Group-Share), Theory of Computation, t-Test, Likert's Scale.

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1. Introduction

Mathematics has a wide range of applications in engineering and technology for simulation study and product development. However, students generally find it cumbersome and difficult to learn and apply. Therefore, with a view to make the course interesting and to increase its applicability in application domain, a few innovative methodologies need to be incorporated in teaching-learning process.

TPS activity is very effective and popular for use by instructors of large classes. This technique engages the entire class, motivate students and promote higher-level thinking. It helps students to think individually about a topic, share ideas with classmates, builds oral communication skills, focus attention and engage students in understanding the reading material. Since TPS consist of three phases- Think, Pair and Share, for some complex examples, working in pair is not sufficient to solve the problem. Therefore, more than two students in a group are required to attempt and solve the problem. Hence, in the current study, the TPS method is modified and one more phase is added to it. The modified TPS activity, T24S is generally useful for mathematical courses like theory of computation, mathematics etc. Here the case study of mathematical subject like Theory of Computation course of Computer Science and Engineering is considered.

2. Related Work

The authors (Carlos I. Chesˇnevar et al., 2003) discussed the main features of software tools currently freely available via the Internet for teaching formal languages and automata theory. 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. The authors (Mukta Goyal and Shelly Sachdeva, 2009) in "Enhancing Theory of Computation Teaching through Integration with other Courses" aimed towards introducing different approaches

for making the course interactive and realistic by integrating it with other courses learnt in previous semesters and current semester of engineering like Programming Language, Data Structure, etc.

The authors (Carlos I. Chesˇnevar et al. , 2004) in "Didactic Strategies for Promoting Significant Learning in Formal Languages and Automata Theory" introduced 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 this subject etc. while the authors (Carlos Iv´an Chesˇnevar et al., 2004) in "Teaching Fundamentals of Computing Theory: A Constructivist Approach" were proposed a strategies based on a stronger use of technology and a constructivist approach.

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 (S. H. Rodger et. Al., 2006) while a pioneer Intelligent Tutoring System (ITS) called FLUTE was considered for teaching formal languages and automata (V. Devedzic et. Al., 2000).

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).

TPS activity and modified TPS activity $TP_{FOSS}S$ to teach Theory of computation is already considered and result are also improved (Sunita M Dol , 2014) (Dr. S. A. Halkude and Sunita M. Dol, 2015). While the goal of study (Aditi Kothiyal et. al., 2013) was to understand student behavior in an implementation of an active learning strategy, Think-PairShare, operationalized for a large CS1 class.

$TP_{FOSS}S$ activity is also useful for teaching Compiler Construction course (Sunita B. Aher and Dattatray P Gandhmal, 2014). However, $TP_{FOSS}S$ activity can be employed only to those courses for which free open source simulation software are available. For the course considered over here which is mathematical in nature T24S is found to be more effective. Therefore in this paper, modified TPS activity T24S is considered which can be used effectively for mathematical subjects.

3. Methodology used

The objectives of this study are:

- To prepare the fundamentals of the course Theory of Computation.
- To improve the students' performance in the examination.

For testing the effectiveness of T24S activity, one group Pre-Test Post-Test model is considered. The course considered is Theory of Computation which is Second Year Computer Science and Engineering Course. Simplified forms and normal forms is the topic considered from this course for conducting this activity.

A. What is TPS?

TPS is a collaborative, active learning strategy, in which students work on a problem posed by instructor, first individually (Think), then in pairs (Pair) or groups, 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, used during Guided Reading lessons, on reading achievement. So this TPS consist of three phase (Susan Ledlow, 2001 and http://www.hydroville.org/system/files/team_thinkpairshare.pdf) as shown in figure 1:

Think: Faculty starts the teaching-learning process by seeking answers to specific question about the topic. Students 'think' about what they know or have learned about the topic for a given specified time slot.

Students do: Write down answer to the question.

Instructor does: Encourage students to write the solution of problem. (www.et.iitb.ac.in/TeachingStrategies.html)

Pair: Each student is paired with another student. Students share their solution to given problem in think phase, discuss ideas, and ask questions to each other. Faculty asks complex question related to previously asked problem and students are asked to solve the problem.

Students do:
(i) Identify parts of the answer that they have missed out.
(ii) Discuss which answer is better; do pros-cons analysis if there are multiple solutions.

Instructor does:
(i) Walks around the class to get a feel of students' solutions.
(ii) Gives comments where necessary (www.et.iitb.ac.in/TeachingStrategies.html).

Share: Pair has adequate time to share their thoughts and have a discussion; teachers expand the "share" into a whole-class discussion. Allow each group to choose who will present their thoughts, ideas, and questions. After the class "share," you may again ask the pair to talk about how their thinking changed as a result of the "share" element.

Students do:
(i) Share their own solution.
(ii) Critique others solutions.

Instructor does: Discusses regarding
(i) What are all the essential parts in the answer?
(ii) Pros-cons of various solutions given by students
(www.et.iitb.ac.in/TeachingStrategies.html).

Figure 2 shows the activity performed by instructor and students during TPS activity.

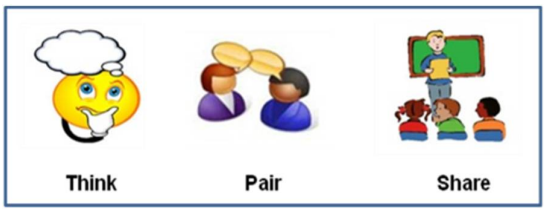


Fig. 1: TPS activity

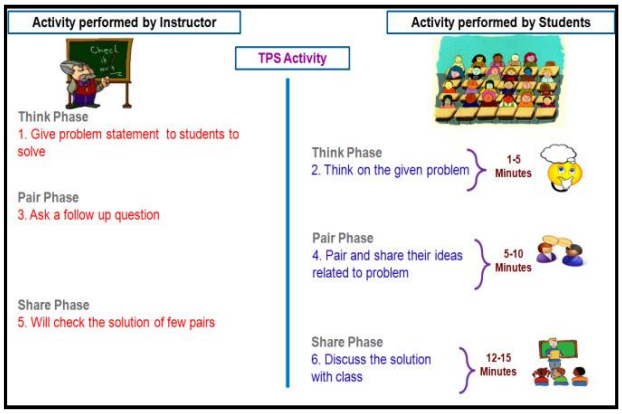


Fig. 2: Activity performed by instructor and students during TPS activity

B. TPS Activity for Theory of Computation

The topic considered for this activity was – Simplified Forms and Normal Forms. So the problem statement was to convert the given context free grammar to Chomsky Normal form which consist of following steps (John C. Martin, 2003):

Step 1: Eliminate null productions from given context free grammar if any.
Step 2: Eliminate unit productions from given context free grammar if any.
Step 3: Eliminate useless variable from the productions of given context free grammar if any.
Step 4: Convert the context free grammar to Chomsky Normal Form.

The steps to convert the following context free grammar to Chomsky Normal form are given in figure 3:

S -> ABA
A-> aA| ^
B -> bB | ^

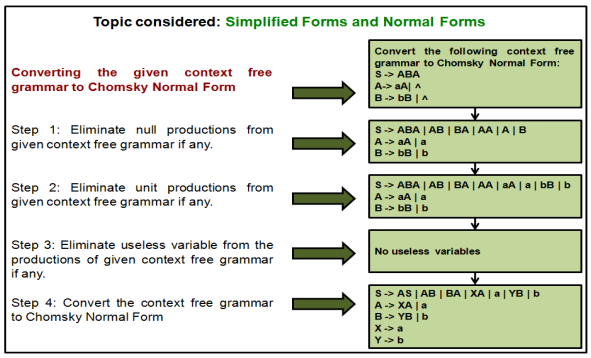


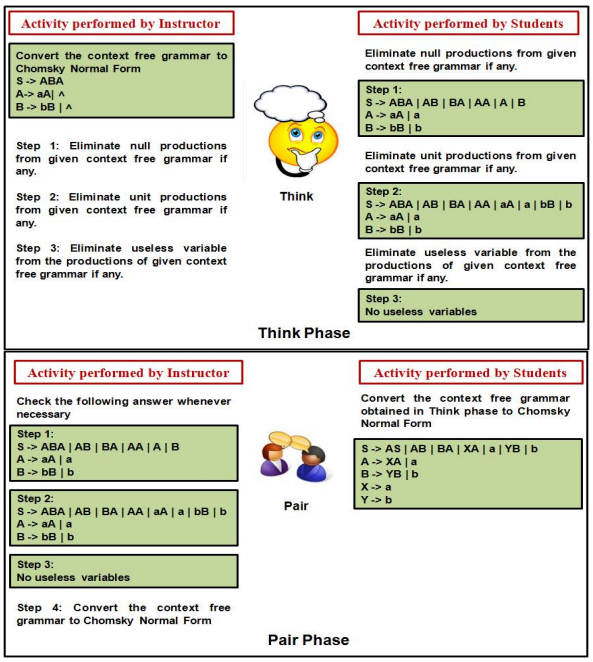
Fig. 3: Conversion of context free grammar to Chomsky Normal form

TPS activity for converting the given context free grammar to Chomsky Normal form which is given in figure 4 consist of

Think: In the think phase of TPS activity, instructor asked the question to students to eliminate null productions, unit productions and useless variable if any from given context free grammar.

Pair: The students were asked to convert the grammar obtained in the 'Think' phase to Chomsky Normal form.

Share: In the share phase, students shared the solution with the entire class. Instructor discussed the problem of converting context free grammar to Chomsky Normal form and highlights important points



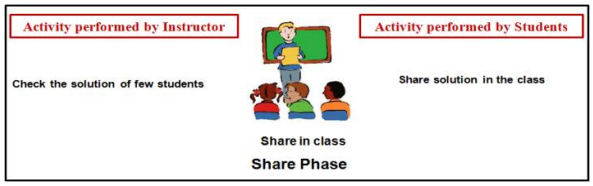


Fig. 4: TPS activity for converting CFG to CNF

C. Improving TPS to T24S

For more complex examples, TPS has got a limitation since it has only two members in pair phase. For broadening the thinking base and using the collective wisdom, TPS is modified as T24S by introducing one more phase that is by adding two more students and enhancing a geroup strenth from two to four.

D. What is T24S activity?

In T24S which is given in figure 5, students first think individually, discuss problem-solving strategies in pairs and then in groups of four students followed by share phase. Since problem solving strategies can be complicated, this structure may be more appropriate with experienced collaborative groups.

Fig 5: T24S activity

T24S activity for converting context free grammar to Chomsky Normal Form is given in the following figure 6 for the same example.
T24S activity consists of four phases:

Think: In think phase of TPS activity, instructor asked the question to students to eliminate null productions if any from given context free grammar.

2(Pair): In this phase, instructor asked the students to eliminate unit production and useless variables if any from the grammar obtained in Think phase.

4(Four students in group): The students were asked to convert the grammar obtained in '2(Pair)' phase to Chomsky Normal form.

Share: In share phase, students shared the solution with the entire class. Instructor discussed the problem of converting context free grammar to Chomsky Normal form and highlights important points.

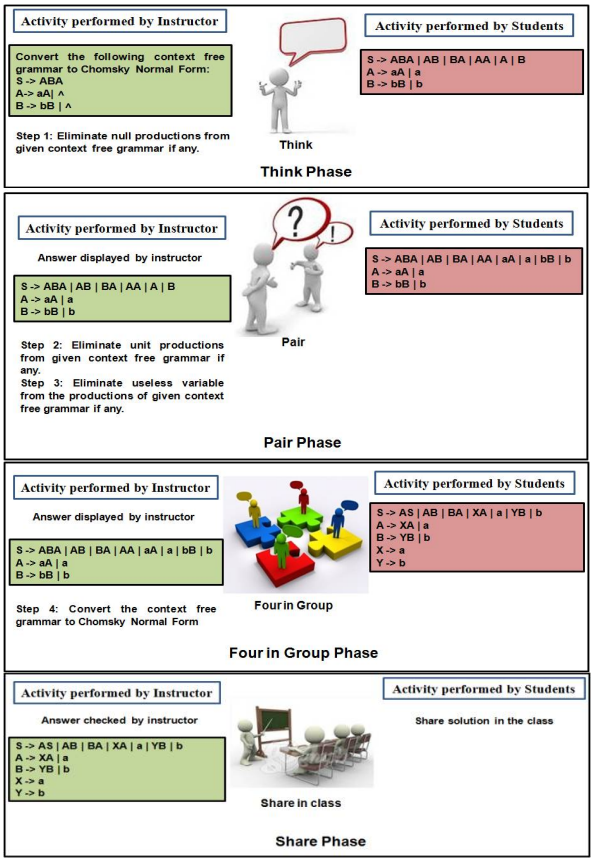


Fig. 6: T24S for converting CFG to CNF

E. Advantages of T24S in addition to TPS

In addition to TPS method, T24S activity has following advantages:

- More Ideas can be discussed and shared.
- It improves communication skills.
- Group discussion enables the participating candidates to think in divergent directions to generate more points and a good presentation of the topic in the group
- Group discussion enhances the learning.
- Different minds discussing about a topic, generate good questions and find the relevant answers

4. Experimental Detail

A. Experimental Set-up

The experimental set-up for this study is shown in figure 7.

Techniques used	$TP_{FOSS}S$ (Think-$_{PairFree\ Open\ Source\ Software}$-Share)
Course	Theory of Computation of Second Year
Sample	One group of 40 students from Second Year Computer Science and Engineering of Solapur University
Method	One group and a pre-test post-test model
Instruments used	1. Pre-test 2. Post-test 3. Survey questionnaire and feedback from open ended questions
Learning Domain used	1. Bloom's Taxonomy Cognitive domain – Analysis level

Fig. 7: Experimental details

B. Research Design

In the present study, one group Pre-Test Post-Test Model was considered. Instructor taught the topic Simplified Forms and Normal Forms using traditional teaching method i.e. blackboard teaching method. After teaching this topic, Pre-Test was conducted on this topic. Two TPS activity was conducted to convert the given context free grammar to Chomsky Normal Form. Post-test1 was conducted on this topic. After post-test1, two T24S activity was conducted followed by post-test2. To know about the students' perception about activity, feedback was also conducted at the end of TPS and T24S activity. The research design is shown in figure 8.

C. Pre-Test and Post-Test

Pre-Test and Post-Test were conducted on the topic: Simplified Forms and Normal Forms. The weightage of both tests was 30 marks. Both tests consist of questions like eliminate null productions, eliminate unit productions, eliminate useless variable and convert the given grammar into Chomsky Normal Form. These questions cover Apply and Analyze level of Bloom's Taxonomy. The sample question in tests is shown as below:

Convert the following context free grammar to Chomsky normal form S-> bAC , A-> C|a, B-> bAE , C-> cC|B|^ E-> cE , D -> dFA, F -> e

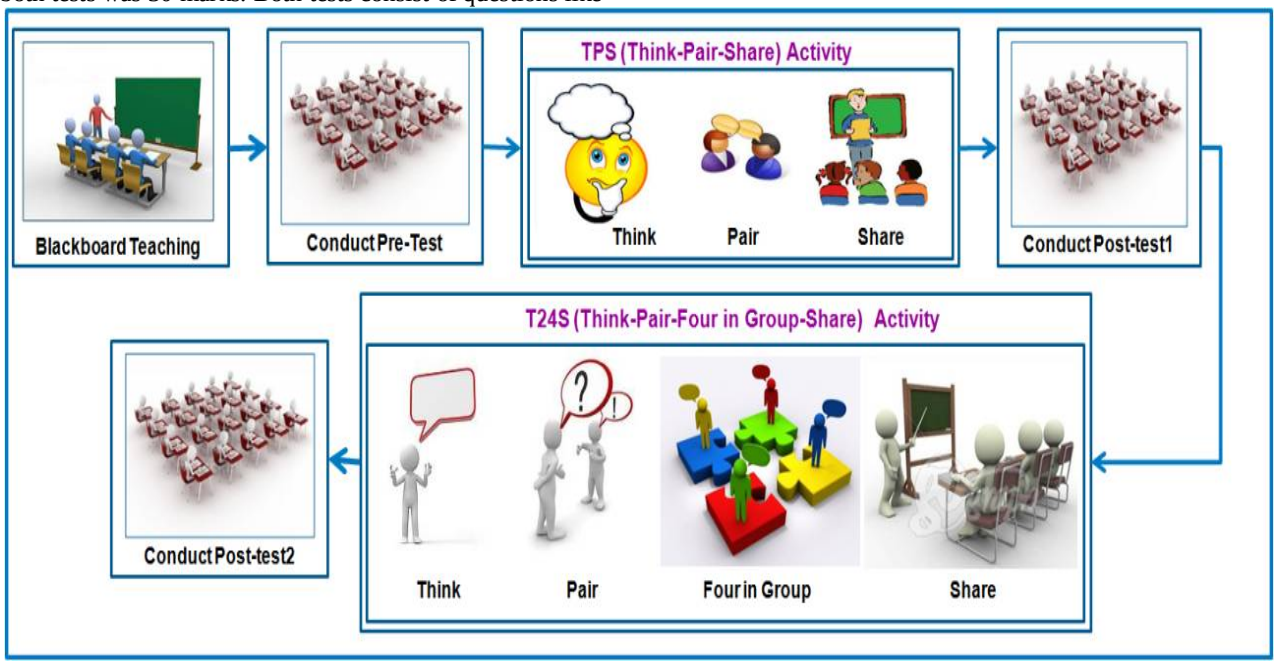


Fig. 8: Research design

D. Feedback

To understand students' perception about T24S activity, the feedback was conducted at the end of activity as shown in figure 9. It is found that 100% students liked this T24S activity.

S.N.		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%
		Strongly Disagree	**Disagree**	**Agree**	**Strongly Agree**
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=100%			

Fig. 9: Feedback

E. Other Active Learning Strategies considered for Theory of Computation

In addition to the modified TPS activity, following active learning strategies are considered:

- Free Open Source Software like JFLAP and
- $TP_{FOSS}S$ for Minimization of DFA states and
- Pair-Share method

1) Free Open Source Software JFLAP:

JFLAP: It is an instructional tool for visualizing and interacting with many concepts in automata theory and formal languages including regular languages, context-free languages, and recursively enumerable languages. JFLAP focuses on several types of parsing including Brute-force parsing, LL (1) parsing, SLR (1) parsing and CYK parsing [18].

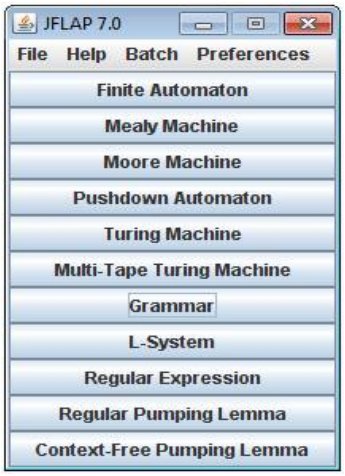


Fig. 10: JFLAP tool

2) $TP_{FOSS}S$ for Minimization of DFA states

$TP_{FOSS}S$ to teach the topic "Converting Context Free Grammar to Chomsky Normal Form" of Theory of computation is already considered and results are also improved [9]. This year, this activity was considered for minimization of DFA states.

3) Pair-Share Method in Tutorial Session

In tutorial session, a group of two students was formed to solve the exercise problem for each assignment of Theory of Computation. After solving the exercise problems in pair, then students shared the solution with the class.

5. Results Analysis

Students' conceptual understanding was analysed using pre-test, post-test1 and post-test2 marks as shown in figure 11. Graph in figure 10 shows that students performed better in post-test2 as compared to pre-test and post-test1.
Statistical analysis using t-test for pre-test and post-test1 & for post-test1 and post-test2 is given in table 1 and 2. In table 2, since p=0.0001, t-Test result also shows statistical significant difference between post-test1 and post-test2 conducted for this activity

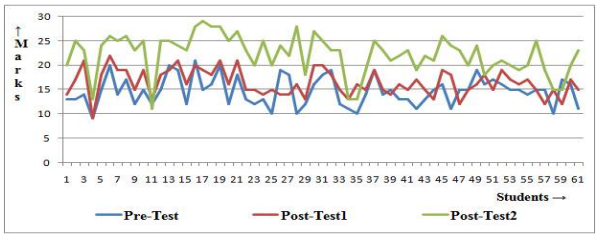


Fig. 11: Performance of Students in pre-test, post-test1 and post-test2 in Theory of Computation

Table 1: Statistical Analysis using t-Test Result for pre-test and post-test1

Degree of Freedom	Standard Deviation	t value	p value
120	2.84	3.35	0.0011

Table 2 : Statistical Analysis using t-Test Result for post-test1 and post-test2

Degree of Freedom	Standard Deviation	t value	p value
120	3.44	9.33	0.0001

University result of 2015 Shift-II batch for which these activities were conducted was compared with 2014 Shift-II batch. The graph which is shown in figure 12 shows the significant improvement in students' performance of 2015 Shift-II batch as compared to 2014 Shift-II batch.

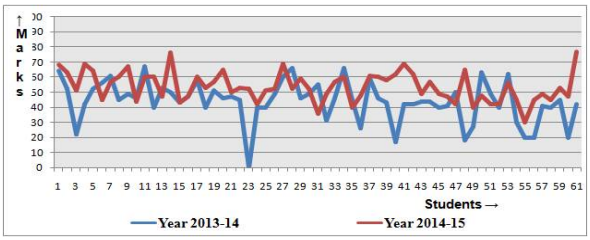


Fig. 12: Performance of Students in university examination in Theory of Computation

t-Test result also shows statistical significant difference between students' performance of 2015 Shift-II batch as compared to 2014 Shift-II batch which is shown in table 3.

Table 3 : Statistical Analysis using t-Test Result of university examination (year 2013-14 and year 2014-15)

Degree of Freedom	Standard Deviation	t value	p value
120	11.8	4.58	0.0001

6. Conclusions

TPS is a simple and effective formative assessment technique which identifies and addresses areas of confusion for students and allows instructors to address the confusion in helpful manner. TPS allows instructor to access students' degree of learning. This T24S- variation of the standard TPS adds another pair of students to work together. The addition of one more phase in the TPS activity that is T24S activity is found to act as catalyst for problem solving strategies and complex problems that involves more than one step or possible multiple answers. This paper illustrates the way T24S- the modified TPS activity can be employed for mathematical courses. In the present study, the case study of mathematical course like Theory of Computation in Computer Science and Engineering is considered. It is found that modified TPS activity T24S and other active learning strategies considered for teaching the Theory of Computation course improved the performance of students significantly.

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