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# Application of Paired Problem Solving for Effective Identification of Misconceptions

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***Abstract*— In engineering education, most courses have numerical problems and complex concepts that need to be applied. Students sometimes find it difficult to apply the concepts in numerical problems and subsequently end up performing poorly in examinations. Timely feedback on numerical problems solved by the students will address this. A systematic understanding of student misunderstandings and misconceptions is likely to lead to improved effectiveness in learning. TAPPS (Think Aloud Paired Problem Solving) is one of the best practices in engineering education and provides an opportunity for students to solve problems collectively by thinking and sharing their individual thoughts and ideas. When the instructor is involved as a keen observer the student misconceptions can be documented comprehensively enabling the instructor to address the problem in a timely manner. TAPPS also provides ample scope for educators to identify individual thinking processes and understanding patterns and therefore enables them to guide the students towards the correct approach to problem solving. This article describes a case study of an implementation of TAPPS with a dialogue conducted for undergraduate electrical engineering students in the third year.**

***Keywords*—TAPPS, Numerical Problem Solving, Heterogeneous groups**

***JEET Category*—Practice**

## I. Introduction

Student misunderstanding and misconceptions are major hindrances in the learning processes of Engineering subjects (Trotskovsky et al., 2013). A misconception can be a wrong opinion or belief in one's mind, this further leads to a series of errors and mistakes based on their flawed understanding (Makonye et al., 2012). The reason for encountering an error or mistake while procedurally solving a mathematical problem is an inadvertent departure from the truth. Furthermore, the author emphasized that errors can also occur due to a student's misjudgment or carelessness which could be remedied through practice. (Mulungye et al., 2016).

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J. Weliwita et al., (2020) strongly state that the student academic performance in the Engineering stream at the University was greatly impacted by prior misconceptions and that therefore the educator needs to track student understanding and identify potential misconceptions in undergraduate courses and attempt to address through various pedagogical techniques. Unearthing and understanding misunderstandings and misconceptions of students are made more effective by probing students' underlying assumptions through questions and guiding students to construct better understanding by themselves. The role of prior knowledge in learning is well documented in current educational research literature (Bransford, et all 1999).

## II. Literature Review

Think Aloud Pairing and Problem Solving (TAPPS) is an approach to student engagement based on metacognition. It allows the student to work in pairs to solve the problem, one in the role of problem solver, allows him to think and verbalize the thought process and solves the problem; meanwhile other students keenly observed the problem solver's thoughts and the roles were interchanged for a different problem (Abdul Kani, et al., 2015). Collaborative learning enhances the learning skills of students (K. Ramprathap et al 2019). The TAPPS technique is a collaborative learning method that enhances the problem-solving skills of learners, this peer learning approach applicable for various disciplines including technical courses.,the author implemented TAPPS activity for Automobile Engineering Students by forming the student batches of 4 or 5 members each and had them work together and solve the problem, during the process, the instructor acted as an observer and graded based on performance and the activity ended with a discussion of the correct answer (S. S. More et al., 2023). In (Engelmann et al., 2011], the author focused on the significance of misconceptions and claimed that addressing misconceptions improves the learning process. In the article (Patil, et al., 2019) the authors described different types of misconceptions and their sources and also presented a detailed discussion about tools and techniques to identify the misconceptions. One can summarize that the identification and addressing of misconceptions plays a crucial role in the learning process, however there are very few references available on effective identification and addressing the misconceptions. Students struggle to handle numerical problems and the failure rate is high in external examinations. In regular teaching, although the educator delivers content very effectively in the class, he doesn't know to what extent and in what way the student has received the concepts and/or understood how to apply the concepts learnt. This article describes the steps involved in setting up the student pairs and assigning numerical problems with variations to the different student pairs in the class. After setting up, TAPPS was implemented and student misconceptions were identified systematically and were addressed in the class in a timely manner.

## III. METHODOLOGY

The case study was conducted for third -year second -semester Electrical and Electronics Engineering students in a Power Systems Analysis course. Course outcomes are truly one of the imperative tools used in the teaching assessment process in education.(Durga Prasad et al 2021). The learning outcomes for the course are described in Table 1 below

TABLE I
COURSE OUTCOMES

At the end of the course, the students should be able to:

| | |
|---|---|
| CO1 | Represent the per unit quantity representation and develop per unit reactance diagram and Y bus matrix of a power system network. |
| CO2 | Develop Z bus matrices of a power system network by using different techniques. |
| CO3 | Solve load flow problems of the interconnected power system network by different iterative methods. |
| CO4 | Perform symmetrical short circuit analysis. |
| CO5 | Perform unsymmetrical short circuit analysis with due understanding of power system stability. |

TABLE II
ACTIVITY DETAILS

| | |
|---|---|
| Course name | Power Systems Analysis |
| Year & Branch | III year II semester |
| Topic | Numerical problems on Unsymmetrical fault analysis of unloaded synchronous generator |
| Course Outcome | CO5 in Table 1 |
| No. of students | 54 |
| No. of groups | 21 |
| Students per batch | 2 or 3 |
| Duration of activity | 50 Minutes |

Table II above shows the details of the activity. The activity described in this paper was conducted for the 2019-20 cohort of students and relates to one specific learning outcome (CO5-Perform unsymmetrical short circuit analysis with due understanding of power system stability in Table 1) in this course.

The theory and concepts relevant to the topic above was covered in the earlier class session and the TAPPS activity was conducted in the next class session. Below is the detailed procedure to conduct activity.

Step-1 Form student pairs and groups

Step-2 Assign different problems on selected topic

Step-3 Allow students to solve the problem in their groups

Step-4: Monitor student groups and interact with them as needed. Document observations for each group (Table VI)

Step-5 Write the activity report along with the list of misconceptions. (Table VII)

Step-6 Take the appropriate remedial action

### *A) Form student groups*

Student grouping was done based on their academic performance from previous semester end examination results. Research shows that mixed-ability grouping / heterogeneous grouping allows for the exchange of ideas and perspectives, leading to deeper understanding [B. Cernilec et al., 2023]. Table III illustrates the details of categorization of students for grouping. The groups are formed in such a way that in each group at least one student is from category 1, and one or two from category 2 or category 3.

TABLE III
STUDENT GROUPING DETAILS

| | |
|---|---|
| Category 1 | 0 Fail Grades up to previous semester |
| Category 2 | < 5 Fail Grades up to previous semester |
| Category 3 | > 5 Fail Grades up to previous semester |

### *B) Assign different problems on selected topic*

Four problems were given on selected topics as shown in "Fig.1". Table IV is the representation of "Fig.1" for clarity; these problems were assigned to the different groups. All the problems were of equal difficulty with different parameters used to result in uniquely different answers.


Fig. 1 Different model problems on selected topic

TABLE IV
DIFFERENT MODEL PROBLEMS ON SELECTED TOPIC

| | |
|---|---|
| Problem Number 1 | 3-∅, Synchronous Generator, $X_1$ =j 0.5 P U, $X_2$ = j0.35=PU, $X_0$=j0.10 PU, MVA=25, KV=13.2. LG fault on Generator terminals, $Z_f$ =0, $Z_n$=0. Calculate Fault current $I_f$, Line-Line voltages. |
| Problem Number 2 | 3-∅, Synchronous Generator, $X_1$ =j 0.5 P U, $X_2$ = j0.35=PU, $X_0$=j0.10 PU, MVA=25, KV=13.2. LG fault on Generator terminals, Zf =j0.1PU, Zn=j0.6PU. Calculate Fault current If , Line-Line voltages |
| Problem Number 3 | 3-∅, Synchronous Generator, $X_1$ =j 0.5 P U, $X_2$ = j0.35=PU, $X_0$=j0.10 PU, MVA=25, KV=13.2. LL fault on Generator terminals, Zf =0, Zn=j0.4PU. Calculate Fault current If , Line-Line voltages |
| Problem Number 4 | 3-∅, Synchronous Generator, $X_1$ =j 0.5 P U, $X_2$ = j0.35=PU, $X_0$=j0.10 PU, MVA=25, KV=13.2. LL fault on Generator terminals, Zf =j0.2, Zn=∞. Calculate Fault current If , Line-Line voltages. |

*C) Allow students to solve the problem in their groups (30 minutes)*

Table V shows the assignment of problems to the student groups. After assigning the problem, the instructor asked the student groups to solve the problems. The "Fig.2" shows student batches are seriously involved in problem solving. Without pairing of students, the instructor was not able to ensure every student was involved. With pairing, every student is compelled to participate.

TABLE V
PROBLEM ASSIGNMENT

| GROUP NUMBER | PROBLEM NUMBER |
|---|---|
| 1, 5, 9, 13, 17, 21 | 1 |
| 2, 6, 10, 14, 18 | 2 |
| 3, 7, 11, 15, 19 | 3 |
| 4, 8, 12, 16, 20 | 4 |

Fig. 2. Student groups solving problems

*D) Monitoring of Student Groups and Documenting Report*

Monitoring of student groups plays a very important role in this activity, here the educator plays an observer role as illustrated in "Fig.3" and carefully examines the student groups in the following aspects.

1. Individual thinking process towards problem solving.
2. Student understanding pattern based on question.
3. Points of struggle in solving the problem.

In this step, the educator can directly interact with the student batches and try to understand their thinking. Further, a dialogue approach was used to directly ask them about the challenges and difficulties facing in solving the problems which triggered their thinking and metacognition. Finally detailed reports on observations for each group were made. "Fig. 4" shows the instructor making notes of the observations while interacting with one of the groups.

Fig. 3. Monitoring the student groups

Fig. 4. Report on observations for each group

*E) Write the activity report along with the list of misconceptions*

In total 11 out of 21 groups had errors, Table VI below represents observations and Table VII shows the corresponding misconceptions for each group

TABLE VI
OBSERVATIONS

| Group no. | Observation |
|---|---|
| 5, 8, 19 | Mixed up appropriate fault conditions |
| 10, 12 & 18 | Mistakes in calculation of effective zero sequence impedance |
| 3 | Not knowing how to convert per- unit values to actual values. |
| 8 &16 | Wrong impedance diagrams |
| 1, 13 | Calculation errors |

TABLE VII
LIST OF MISCONCEPTIONS CORRESPONDING OBSERVATIONS

| Group no. | Misconception |
|---|---|
| 5, 8, 19 | Fault conditions are the same with fault impedance and without fault impedance. |
| 10, 12 &18 | Omitted the neutral impedance effect, assuming that the effective zero-sequence impedance will be the alternator's corresponding zero-sequence impedance. |
| 3 | Assumed that the choice of base current was arbitrary (instead of calculating from base power and base voltage). |
| 8 &16 | Mixed positive sequence impedance with negative sequence impedance. Assumed that negative sequence impedance also has a source. Ignored neutral impedance and fault impedance. |
| 1, 13 | Ignoring imaginary part when doing Fault calculation in complex notation. |

Table VI identifies the type of error done by the students, whereas Table VII describes the underlying misunderstanding or misconception. For instance, one of the major errors students made is in the calculation of effective zero sequence impedance and the related misconception that it revealed was that students omitted the neutral impedance effect, assuming that the effective zero-sequence impedance will be only the alternator's corresponding zero-sequence impedance.

*F) Appropriate remedial action*

The appropriate remedial action must be done based on the type of misconceptions; the following are the various types of remedial actions to fix the misconceptions.

1. Address and discuss the root of the misconceptions clearly with the students. This is possible for simple misunderstandings and misconceptions by making the students think.
2. Conduct tutorials. This is needed for deeper understanding needed to solve numerical problems with varied parameters.
3. Giving follow up assignments. This may be needed depending on the depth of the errors.

## IV. RESULTS AND DISCUSSIONS

The TAPPS activity made it possible to address the different misconceptions mentioned in table VII from the diversity of groups illustrated in tables VI and VII. Without the activity, the details of the misconceptions will not have been available to be addressed. Addressing misconceptions followed by conducting a tutorial session was the remedial action done in this case study. After remedial action, a second assessment was done by assigning problems to students in a mock exam. Table VIII illustrates the performance of the students before and after the remedial actions based on the mock exam which shows the improvement in the students problem solving ability.

TABLE VIII
IMPACT OF ACTIVITY ON STUDENT PERFORMANCE

| % of Students with minimal errors in responses in the mock exam | |
|---|---|
| Before remedial action | After remedial action |
| 50% | 81.5% |

The activity described above can be replicated in other topics/ outcomes in the same course or a different course as well. Over time, the instructor can identify the list of misconceptions corresponding to all the topics in the course. This list of misconceptions helps educators to teach effectively for upcoming batches. Table IX below shows the impact of activity on end semester exam results. It is interesting to note that the number of students not attempting the question related to this outcome was the lowest when TAPPS with feedback was done in the year. It is assumed that the preparation level of the students was improved as a result of this activity because of deeper discussions. This is a possible reason for the improved confidence level of the students resulting in the larger percentage of students attempting the questions. Further the percentage of students with F grade in the end exam has reduced significantly after the introduction of TAPPS.

TABLE IX
IMPACT OF ACTIVITY ON STUDENT PERFORMANCE

| Academic Year | Activity | Percent Students who did not attempt question | Percent Students with 'F' Grade |
|---|---|---|---|
| 2018-19 | None | - | 18.4% |
| 2019-20 | TAPPS | 3.9 | 7.1% |
| 2020-21 | Tutorials | 10.7 | 9.1% |
| 2021-22 | Tutorials | 8.0 | 4.1% |

The author was the course instructor for four successive academic years, and the activity described here was implemented from the 2019-2020 academic batches onwards. However, the 2020 - 21 academic batches were affected by the COVID pandemic and the classes were conducted in online mode and cannot be compared with earlier batches directly. However, the deeper study of student understanding and misconceptions from the previous year helped the instructor consciously address these topics with more attention to details and spending more time where needed. This is an intangible benefit.

## V Conclusion

Misunderstanding and misconceptions are major hindrances in the learning processes. Problem solving skills are important in engineering courses. Student centered reflective learning practices such as TAPPS enable better student engagement and therefore better learning gains. Observation and facilitation skills are needed to maximize the impact of these approaches. A deeper understanding of the students' misunderstandings and misconceptions improves the effectiveness of teaching and reduces problem solving errors in students. In the longer term, such approaches enable the teacher to become more effective as a teacher and move towards teaching higher level learning outcomes

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