Mahatma Education Society's
Pillai College of Engineering, New Panvel

Department of Mechanical and Automobile Engineering

A REPORT ON
PROJECT BASED LEARNING

2019-2020

Class: Second Year CBCGS **Branch:** Mechanical / Automobile Engg. **Semester:** III

There were two PBL topics that were floated for the student groups to choose from, at the start of the semester. They are: (1) **Column Design Challenge**
(2) **Fidget Spinner**

A minimum of 2 students and a maximum of 4 students were allowed to form PBL groups. There were two stages of evaluation in the semester, a mid-term (Stage 1) and a final (Stage 2) evaluation, in view of ensuring consistency in the work done throughout the semester and preventing last minute hassles. Also, a separate period of 1 hour was allotted to the students per week for planning and carrying out PBL activity.

The **Problem Statement**, **Rubrics** for Stages 1 and 2 evaluations, and the conclusions drawn at the end of the activity are highlighted in brief, as follows.

PROBLEM STATEMENTS

(1). COLUMN DESIGN CHALLENGE

Objectives:

a. Students are required to **design** (find **minimum cross section dimensions**) two miniature columns of different materials, but having the same length and load sustained; so that they are just able to support the load **without buckling** and remain under neutral equilibrium (regain shape after some transverse load causing deflection is removed) when put to **test**.
b. For the designed cross section for each column material, students now need to **calculate the minimum length of the column** required and successively **test it** so that the reduced column is just able to withstand the same load without **crushing**.
c. Lastly, students need to re-test the columns as in (a) and (b) above, with slightly increased loads respectively; so that they can demonstrate failure of columns due to buckling—as in (a) above, and due to crushing—as in (b) above.

Outcomes:

At the end of the PBL course, students will learn—

1. To distinguish between a long and a short column.
2. To apply the use of Euler's and Rankine's formulas at appropriate stages of design, so as to estimate the cross section dimensions (for objective (a) above) or to calculate the minimum length (for objective (b) above).
3. To distinguish between buckling and crushing failures.
4. To understand the concepts viz. minimum area moment of inertia, radius of gyration etc. for columns.
5. To understand the importance of the term—slenderness ratio.
6. To be able to test the column material using standard testing procedures, and estimate its properties.
7. To decide the optimum use of material so as to attain the maximum load lifted per unit weight of the column, leading to the understanding of the concept of 'economy of material'. This is a very important design factor when designing various products, particularly in high-risk and costly applications viz. aeroplanes etc. where saving in material amounts to considerable savings in fuel and hence travelling costs.

Design Guidelines & Specifications:

1. Load to be lifted = 5 kg_f (constant for all calculations and tests).
2. Shape of the columns: Any shape (as long as they are symmetrical along both x-x and y-y axes).
3. Material of the column: Any two materials, for e.g. Hard board (the same that is used for Laser Cutting, in Projects Lab.), steel rods or tubes, aluminium rods or tubes etc.
4. Length of the column [for Objective (a) above] = 1 m.
5. Area available for application of load = 7 cm x 7 cm (square), flat surface. (Hence, the column cross section dimensions are expected to be within this area).
6. No. of columns to be used to lift the load: 1 only.
7. Multi-plying of the column material to create thicker parts of sections (for e.g., in webs and flanges, if I-section is used) is permitted.
8. Columns are assumed to be straight, and of uniform cross section dimensions, along the length, as far as possible.
9. Students may use a standard 2D drafting software (such as AutoCAD or SolidWORKS, for example) to optimize the cross-section satisfying the required minimum area moment of inertia, for use in calculations. All iterations leading to the optimum cross-section may be used in the PBL report.

Rubrics:

1. The **best design of column** is the one that remains under stable equilibrium for the given load, material and length; with the **highest ratio of load lifted to the self-weight of the column**.
2. **Timely completion** of the project work.
3. **Successful demonstration** of learning objectives (a) to (c).
4. The **level of understanding and knowledge gained**, on account of the activity.
5. A **well documented report** with all the required information, both in soft and hard copies.
6. **Delegation of work** among team members etc.

(2). FIDGET SPINNER

Fidget Spinners are toys that are little gyroscopes, which can spin at high speeds with little effort when spun in someone's hands. A basic fidget spinner consists of a usually two- or three-pronged (but can have up to six prongs or more) design with a bearing in its center circular pad. They are made from various materials including brass, stainless steel, titanium, copper, aluminum, and plastic (see picture). Each fidget spinner also has two or more weights on the outside that make it spin faster and stay balanced. Bearings and the moment of inertia can vary to adjust for the design's spin time, vibration, and noise, causing unique sensory feedback.

Fig 1. Fidget spinners in the Project Lab

By examining and studying fidget spinners, we can understand exponential decay, gyroscopic motion, friction, inertia and much more.

In this project, students will design and fabricate their own fidget spinners using at least two different fabrication techniques.

Objectives:

1. Students will design the spinner in Solidworks and estimate its weight and moment of inertia. (submit during Stage-I assessment)
2. Derive an equation for the angular velocity of the spinner as a function of the moment of inertia (I) and bearing frictional damping (b). You can use conservation of angular momentum principles.
3. Select a proper bearing having minimum friction and explain.
4. Students will fabricate the spinner using any material of their choice using two different fabrication techniques (3D printing, lathe, laser cutting, CNC machining etc) and will install a bearing with the minimum amount of friction.
5. They will optimize the spinner for aesthetics and uniqueness of design.

Design Parameters:

1. The maximum diameter of the spinner should be less than 70 mm and the thickness should be less than 20 mm. It could be made by any suitable material.
2. Student should design and install a bearing over which the spinner will rotate. They should research proper bearing installation techniques before finalizing their designs and fabrication. The spinner should spin with minimum friction.
3. A rubber band will be used to give the spinner a suitable standard impulse to get it started. The rubber band will need to either be hooked on one of the prongs of the spinner or attached to it in some other way. Students should consider how the spinner will be attached to the rubber band.
4. The spinner should rotate for a minimum of 30 seconds for a standard input.
5. **Bonus: Students should take a video recording with their phone (or use a non-contact tachometer) to measure the angular velocity of the spinner and produce a graph of the angular velocity vs time for an impulse input. They can estimate the decay time from the graph as well as the time constant and the bearing frictional damping.**

Fig 2: Setup to provide uniform input to the spinner. Students should ensure that a rubber band can be attached to the spinner.

Some Considerations:

Angular Velocity and Exponential Decay: Some people play with fidget spinners in order to improve their spin time. For many, spinning a fidget spinner is a lot less about fidgeting and a little more of a competition. If you have ever spent any time doing this, then you likely understand that it's really hard to drastically improve the spin time and angular velocity (speed) of your fidget spinner. It may make sense from a general perspective that spinning a spinner twice as hard or twice as fast would result in double the spin time, but that isn't even close to what actually happens. This is due to the principle of exponential decay. By observing how the frequency and thus the speed of a fidget spinner changes over time, we are left with a graph that demonstrates some near-perfect exponential behavior. **Can you derive the equation of this graph (angular frequency vs time) from first principles? Can we use this to estimate the bearing friction?**

Gyroscopic Motion: Gyroscopes are spinning devices mounted on an axis used to provide stability to a body through the resistance of motion due to rotational momentum. We can understand this principle when spinning a fidget spinner. If we try to rotate the spinner in a way that is not parallel to its rotational axis, we feel resistance from the spinner itself. Examining this in more detail, we are left with the principle of gyroscopic precession. We can see this at work if we take a fidget spinner and try to tilt it forward. Instead of the spinner tilting forward as one would like, it sort of tilts at a diagonal, relative to the direction the spinner is going. This diagonal rotation is a direct result of gyroscopic precession. Gyroscopic precession is defined when a force is applied to a rotating body, a force appears 90 degrees after the point of impact in the direction of rotation. This is the exact principle at play when using a fidget spinner.

As is customary, students need to furnish a detailed report (preferably typed and printed), both in theory based on reasoning, and also dealing in calculations where required. Students should provide pictures of fabrication process as well as Solidworks drawings and calculations. Neat labeled diagrams should also be included where necessary.

As usual, the PBL work were assessed in **two stages**:

Stage I: August 23, 2019 (Friday): 10 a.m.–12 noon.
Stage II: October 5, 2019 (Saturday): 2 p.m.–5.00 p.m.

Marks for PBL were allotted for the following related subjects, as a part of **term work**:

1. Strength of Materials: 5 out of 25
2. Materials Technology: 3 out of 25
3. Machine Shop Practice: 5 out of 50

MES's Pillai College of Engineering, New Panvel

Project Based Learning – Column Design Challenge

Second Year Mechanical / Automobile Engineering

Stage 1 Evaluation—Rubrics

Class: SE (Mech-A / Mech-B / Auto) **Group No.** _____ **Date:** 23 August 2019

Students' Names: 1.______________ 2.______________ 3.______________ 4.______________ 5.____________

Roll Nos.: ___________ ___________ __________ ___________ __________

Students' Signatures: ___________ ___________ __________ ___________ __________

1. Materials used for column testing: (a) ___________________ (b) _________________
2. Shape of the columns: (a) ___________________ (b) _________________
3. Check whether c/s shape is symmetric about both X-X and Y-Y axes of c/s (Y/N), to avoid combined bending and twisting: (a) ______ (b)______
4. Approximate weight of each column: (a) ___________________ (b) _________________
5. Whether material budget worksheet prepared? ☐ If yes, estimated cost: (a) Rs._____ (b) Rs. ______
6. Whether 5 kgf is supported by the column, under stable equilibrium condition, for **objective 1** of the problem statement? (Y/N): (a) ______ (b)_______
7. Whether proper calculations are done for estimating the c/s dimensions of the column, prior to its construction? (Y/N): (a) ______ (b)_______
8. Whether a report on the Stage-I work prepared and submitted? (Y/N): (a) ______ (b)_______

Overall Rating of PBL Work done (Stage 1):

Best ☐	Very Good ☐	Average ☐	Poor ☐	Needs a lot of improvement ☐
5	4	3	2	1

Evaluators' Signatures: 1.__________ 2. _____________ 3._____________ 4.____________ 5. __________

MES's Pillai College of Engineering, New Panvel

Project Based Learning – Fidget Spinner

Second Year Mechanical / Automobile Engineering

Stage 1 Evaluation—Rubrics

Class: SE (Mech-A / Mech-B / Auto) **Group No.** _____ **Date:** 23 August 2019

Students' Names: 1.______________ 2.______________ 3.______________ 4.______________ 5.____________
Roll Nos.: ___________ ___________ __________ ___________ __________
Students' Signatures: ___________ ___________ __________ ___________ __________

1. Brainstorming session conducted? ☐ If **yes**, how many design ideas generated? ☐
2. Number of fidget spinners to be created? ☐
3. Materials to be used for the fidget spinner/s ____
4. Manufacturing methods to be used for creating the fidget spinner/s _____________ & _______________
5. Number of lobes (prongs) to be used in each fidget spinner: ____
6. Whether material budget worksheet prepared? ☐ If **yes**, estimated cost: Rs.__________
7. Whether CAD solid models/drawings prepared, of the fidget spinner/s? ☐
8. Is the fidget spinner/s manufactured and ready to be tested at this stage? ☐
9. Whether a study of importance and estimation mass moment of inertia of fidget spinners, angular speed been made at this stage? ☐
10. Whether any attempts to understand other concepts in fidget spinners such as gyroscopic effect, exponential decay & its reason for occurrence (aerodynamic drag), breaking/tearing speed required for breaking the fidget spinner etc., been made at this stage? ☐
11. If fidget spinner/s is/are made and ready for testing, it is balanced properly? ☐
    Note: *Have the fidget spinner supported with the help of two fingers and held on either side of the bearing at the centre, and disturb in different angular orientations. If perfectly balanced, then it should not realign itself.*

Overall Rating of PBL Work done (Stage 1):

Best☐ Very Good☐ Average☐ Poor☐ Needs a lot of improvement☐

Evaluators' Signatures: 1.__________ 2. _____________ 3._____________ 4.____________ 5. __________

MES's Pillai College of Engineering, New Panvel
Project Based Learning – Column Design Challenge
Second Year Mechanical / Automobile Engineering
Stage 2 Evaluation—Rubrics

Class: SE (Mech-A / Mech-B / Auto) **Group No.** _____ **Date:** 05 October 2019 **Time:** 2 – 5 p.m.

Venue: P-401 / P402 / P403

Students' Names: 1.______________ 2.______________ 3.______________ 4.______________

Roll Nos.: __________ __________ __________ __________

Students' Signatures: __________ ________ _________ __________

1. Materials used for column testing: (a) __________________ (b) ______________

2. Shape of the columns: (a) __________________ (b) ______________

3. Check whether c/s shape is symmetric about both X-X and Y-Y axes of c/s (Y/N), to avoid combined bending and twisting: (a) ______ (b)______

4. Whether material budget worksheet prepared? ☐ If yes, estimated cost: (a) Rs._____ (b) Rs. ______

5. Whether 5 kgf is supported by the column, under stable equilibrium condition, for objective 1 of the problem statement? (Y/N): (a) ______ (b)_______

6. Whether proper calculations are done for estimating the c/s dimensions of the column, prior to its construction? (Y/N): (a) ______ (b)_______

7. Whether a final report on the work prepared and submitted? (Y/N): (a) ______ (b)______

8. Rate the students' understanding of the project topic: Best☐ Very Good☐ Average☐ Poor☐ Needs a lot of improvement☐

9. What is the maximum reduced length as calculated by the students as in Objective No.2 of the project statement, so that crushing is just avoided? Is it a value the same or other than the original length of 1 m?

10. Rate the understanding of the above concept. If the calculated reduced length value comes out as the same original length (1 m), rate as the best on the scale (5-best, 1-needs a lot of improvement).______________

11. Did students successfully demonstrate the buckling and crushing phenomena for slightly increased loads than 5 kgf? (Y/N)____________. Rate your observation of their performance___________

12. Overall Rating of PBL Work done (Stage 1): Best☐ Very Good☐ Average☐ Poor☐ Needs a lot of improvement☐

Judges' Signatures: 1.__________ **2.** _____________ **3.**_____________ **4.**____________

Mahatma Education Society's
PILLAI COLLEGE OF ENGINEERING, New Panvel
Department of Mechanical & Automobile Engineering
PROJECT BASED LEARNING (PBL) DEMONSTRATION – RUBRICS & ASSESSMENT SHEET

Topic—FIDGET SPINNER Year & Class— S.E.- (MECH-A / MECH-B /AUTO) Date of Demonstration—5/10/2019

JUDGES: 1. Prof.______ 2. Prof. ______ 3. Prof. ______ 4. Prof. ______ 5. Prof. ______ 6. Prof. ________
Signatures: ____________ ____________ ____________ ____________ ____________ ____________

STUDENT GROUP NO.—

NAME						
ROLL NO.						
SIGNATURE						

TERM-WORK MARKS ALLOCATION FOR PBL:

1. Rating given for work in **Stage-I**:
   Best☐ Very Good☐ Average☐ Poor☐ Needs a lot of improvement☐ **Not Reported☐**
2. No. of Fidget Spinners manufactured (1 / 2): ______
3. Manufacturing methods used (minimum 2):
   a.__________________ b.________________
4. Mass of Fidget Spinner/s:________________ grams.
5. Materials used for Fidget Spinner:
   a.___________b.__________c.__________
6. Type of bearing used (sliding/roller/ball):________
7. Specification of bearing used: _______________
8. Inner diameter of bearing: _________ mm
9. Material of bearing (steel/ceramic/hybrid):_______
10. Time taken by Spinner to stop (use Rubber band's potential energy to set spinner in motion):

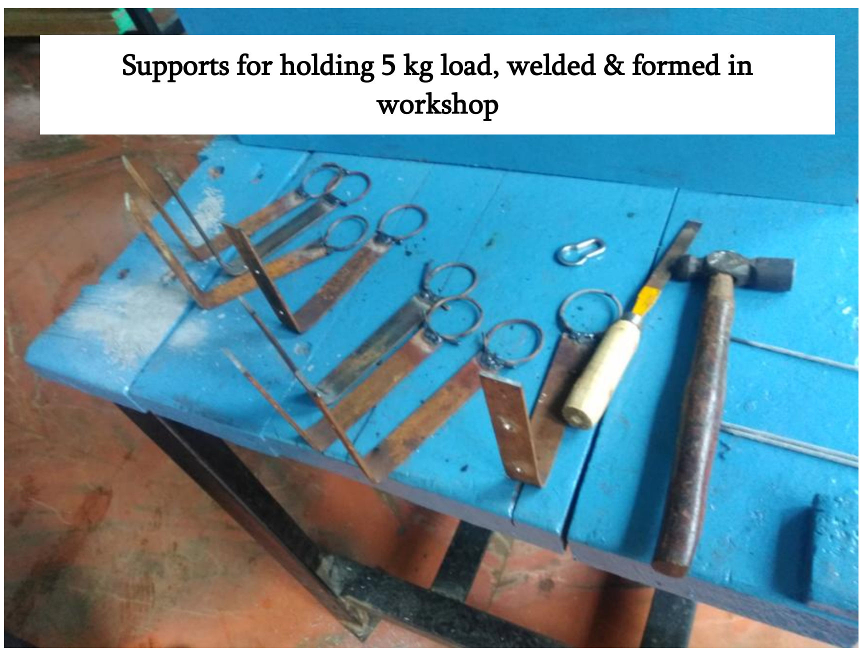
Measured Time to Stop (seconds)	

11. From above, has the hypothesis that doubling the initial angular velocity (by doubling rubber band elongation) doesn't necessarily imply a doubling of time to stop, been confirmed? (Y/N): _________
12. Is the Spinner properly balanced? (Y/N): _________
13. Has Mass Moment of Inertia (I_{GG}) been found? (Y/N):__________ If **Yes**, indicate whether it is obtained from CAD software☐, &/or from analytical formulas☐, &/or from the formula of time period of a compound pendulum☐.
14. Value of I_{GG} found by above method/s (approx.) = __________________ m^2.
15. If multiple methods are used for finding I_{GG}, are these values reasonably close enough, in terms of order of magnitude? (Y/N)__________
16. Whether angular velocity was found, or the data (graph) of angular velocity vs. time obtained? (Y/N)_________. If **Yes**, method used to find angular velocity (experimental / analytical)________
17. Whether aesthetically appealing (form, colour, surface finish, etc.) ? (Y/N):_________
18. Whether Fidget Spinner form and design is unique? (Y/N): ____________
19. Whether additional technical aspects viz. gyroscopic effect during spinning, or limiting rotational speed required for spinner to break apart, etc. explored? (Y/N): ___________
20. If the time required for the manufactured Fidget Spinner to stop—needs to be further improved, then ways suggested by students (also comment whether they were meaningful):
    ____
    ____
    ____
    ____
21. Has the report been properly documented? _______
22. Approx. Cost of the Project: Rs. _________
23. **Overall Build Quality**:
    (Best/V.Good/Avg./Poor/V.Poor)_________
24. **Overall Remarks of PBL Work**:
    Best☐ V.Good☐ Avg.☐ Poor☐ V.Poor☐

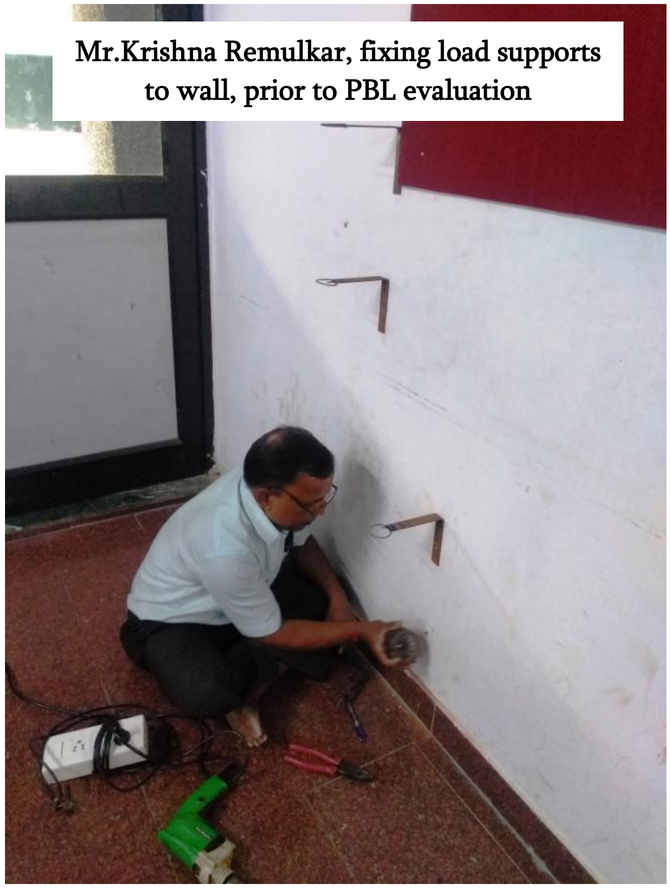
SAMPLE PHOTOGRAPHS of some PBL PROJECTS & EVALUATION:

COLUMN DESIGN

Mr.Hamid Solkar, welding rings to weight-holding brackets in workshop



Supports for holding 5 kg load, welded & formed in workshop

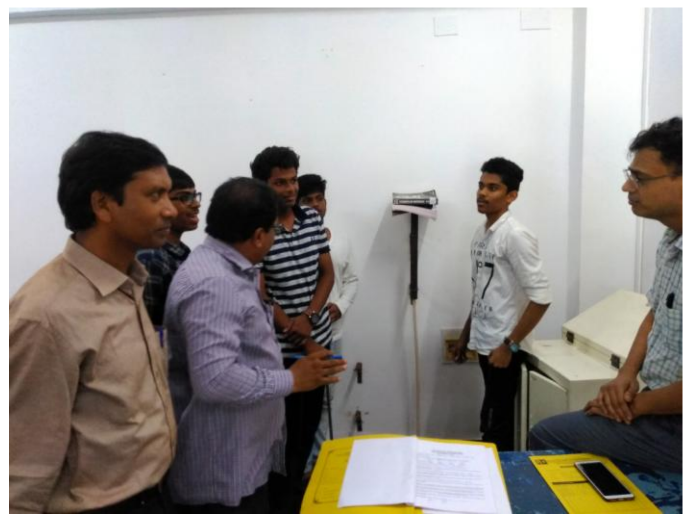


Mr.Krishna Remulkar, fixing load supports to wall, prior to PBL evaluation

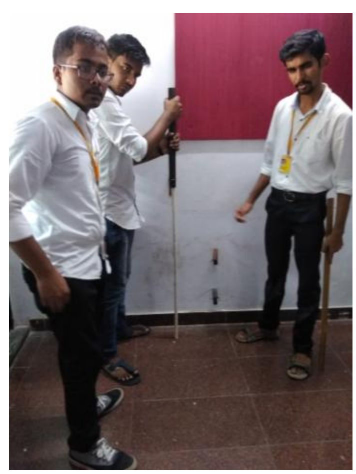
Prof. Lalit Mehta, testing a column under 5 kg load

Students, testing their column
under 5 kg load

Students, testing their column
under 5 kg load



Additional snapshots of students with their miniature columns being tested, under the guidance of faculty members

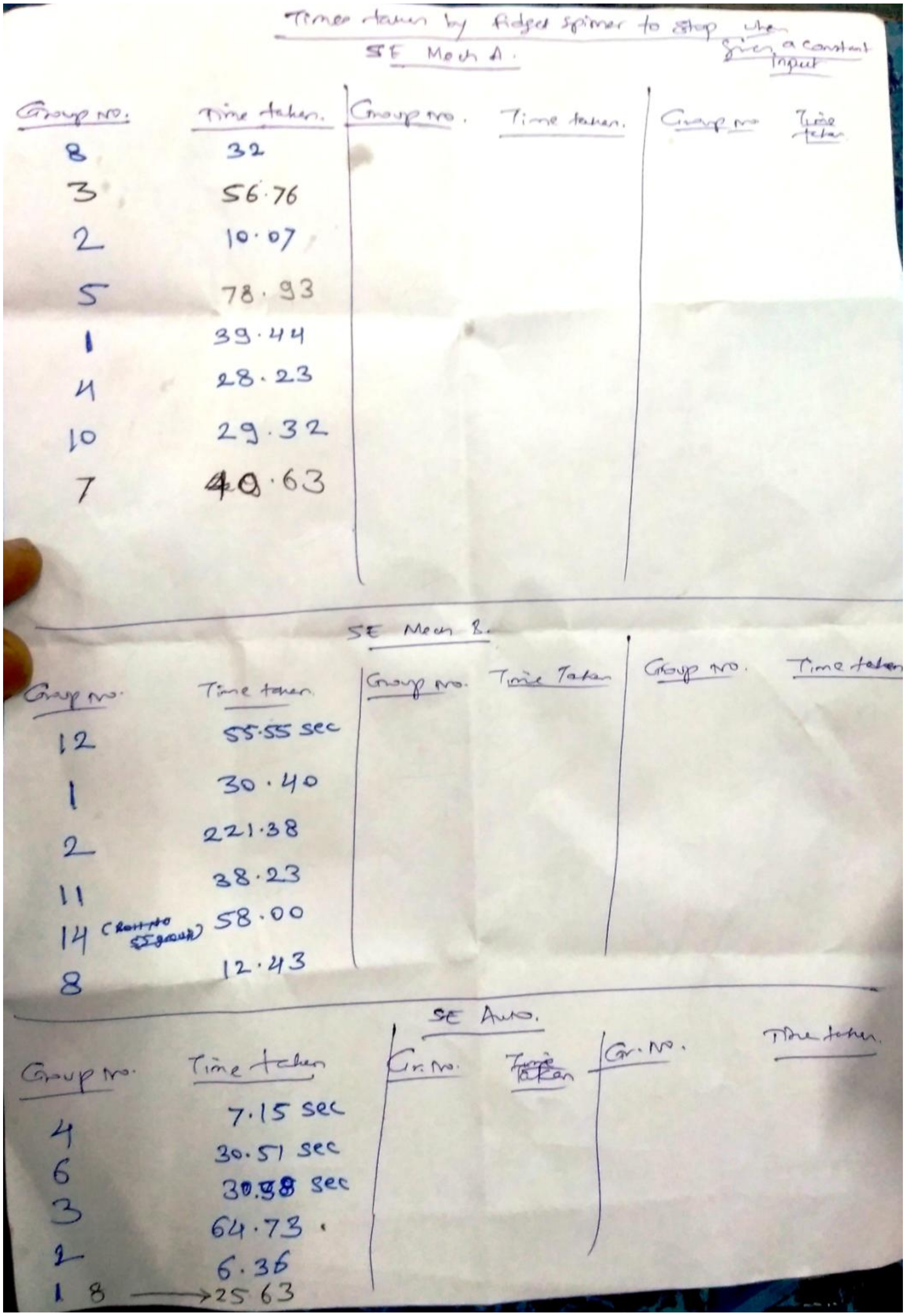


Principal Dr. S M Joshi and COO, Dr. Priam Pillai, having interaction with students during the PBL evaluation

Columns designed by students, with materials ranging from steel, plywood, hardboard, corrugated cardboard, aluminium, PVC etc.

Sample photographs of
FIDGET SPINNER
Evaluation

Test set-up using hardness testing machine and magnetic base holder, for testing times to stop the fidget spinner, given an uniform input to the spinner in the form of potential energy through a stretched rubber band



Time taken by fidget spinner to stop when given a constant input

SE Mech A.

Group no.	Time taken.	Group no.	Time taken.	Group no	Time taken
8	32				
3	56·76				
2	10·07				
5	78·93				
1	39·44				
4	28·23				
10	29·32				
7	40·63				

SE Mech B.

Group no.	Time taken.	Group no.	Time Taken	Group no.	Time taken
12	55·55 sec				
1	30·40				
2	221·38				
11	38·23				
14 (Roll no 55 group)	58·00				
8	12·43				

SE Auto.

Group no.	Time taken	Gr. No.	Time Taken	Gr. No.	Time taken.
4	7·15 sec				
6	30·51 sec				
3	30·58 sec				
2	64·73				
1	6·36				
8	25 63				

Recorded times of various fidget spinners, created by groups from the Mechanical and Automobile departments

Prof. Pankaj Khakare and Prof. Komal Kadam, assessing a group's PBL performance

Use of plastic waste from used bottles, bags etc. to create fidget spinner body, by a Mechanical group of students

The collection of fidget spinners created by Mechanical and Automobile student groups

CONCLUSIONS & OBSERVATIONS

The student groups were found to participate energetically in the project based learning activity, with roughly an equal number of groups pursuing either topic depending on their interests.

The time taken by fidget spinners to stop once an uniform energy was imparted, was found to range from a minimum of about 7 seconds to a maximum of 221.38 seconds (3 minutes, 41.38 seconds !!!), way better than any fidget spinner available in the market.

It was really admirable to see one student group using waste out of plastic from used bottles and bags etc. and manufacturing the fidget spinner body. It's one of the unique PBL activity ideas created so far in the history of the PBL process since inception, in the Institute.

It was found that the PBL objectives set at the start of the activity were largely met, although many groups had difficulty in understanding and putting the theory into practice. Hence, it can be regarded without doubt, that the project based learning is a very efficient tool to implement concepts understood in theory into practice.