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Fostering the cooperative learning of mathematics in engineering schools through the "Teacher-Apprentice" group dynamics

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Background

- Ongoing innovative education project at the University of Malaga, in South Spain
- Running from Sept. 2017 to Sept. 2019 (two academic years)
- First-year students of Bachelor's degrees in Engineering (Mechanical and Electrical Engineering)
- Mathematics subjects (*Calculus*)

Motivation

- Subjects of mathematics are concentrated in the first year of Engineering degrees
  - ✓ The first-year undergraduate student begins to walk the path to become an engineer through the study of Mathematics

- Empirical observations:
  - ✓ High dropout rates
  - ✓ A high degree of frustration and demotivation

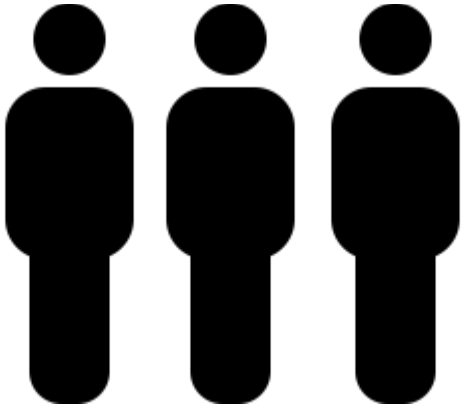
Research question

To which extent engineering students' cooperation can increase their motivation towards the learning of Mathematics?

The “Teacher-Apprentice” method

Teacher

Apprentices



- ✓ Responsible for teaching the Apprentices and overseeing their learning
- ✓ Spokesperson
- ✓ Chosen based on a preliminary test (students with the highest marks)
- ✓ May change based on mid-term examinations

- ✓ Must watch over the benefit of the group
- ✓ Allow themselves to be guided by the Teacher
- ✓ Willing to participate
- ✓ Balanced groups are formed based on the results of a preliminary test

The “Teacher-Apprentice” method

- One group session within the classroom for each thematic unit
- In each session, the teams are asked to solve and discuss a set of math exercises (under the Professor’s supervision)
- They have been requested to work on those exercises before the group session

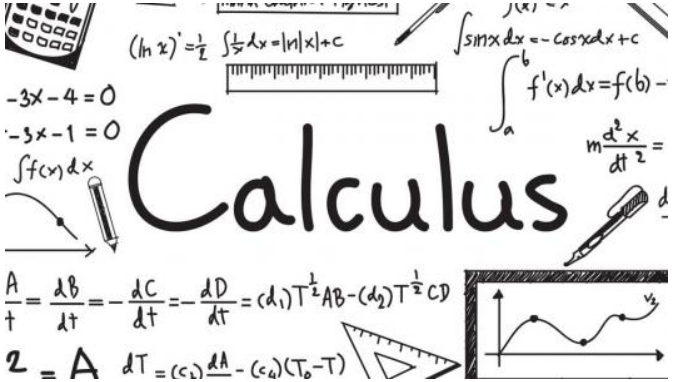
System of Incentives

- Group bonuses for the Teacher:
  1. They are applied after each assessment test (either a midterm or a final examination)
  2. They are applicable as long as the Teacher has obtained a score in the midterm/final examination higher than or equal to 4 out of 10
  3. The bonuses, if applicable, are added to the grade obtained by the Teacher in the midterm/final examination
  4. The Teacher shall receive a bonus of
     - ✓ 0.25 points if only one apprentice has passed the test
     - ✓ 0.75 points if two apprentices have passed
     - ✓ 1.5 points if three or more apprentices have passed
  5. The maximum score that can be obtained in a midterm/final examination, including bonuses, is 10 out of 10

System of Incentives

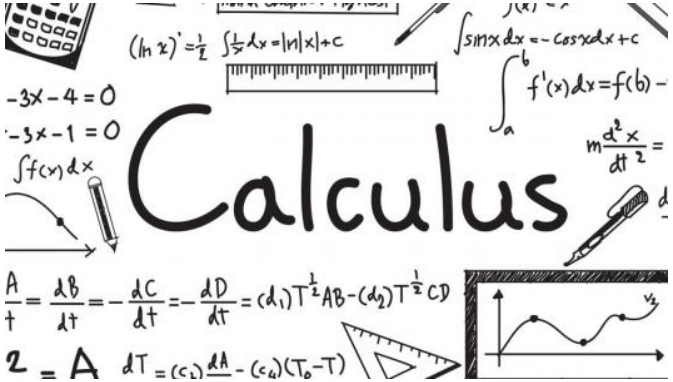
- Group bonuses for the Apprentices:
    1. They are applied after each midterm evaluation test
    2. They are applicable as long as the Apprentice has obtained a score in the midterm examination greater than or equal to 4 out of 10
    3. The group average score is calculated in the assessment test, excluding group bonuses. The Apprentice's grade will be the maximum between the Apprentice's grade on the midterm exam and the group's average grade on that exam

Methodology



First year and first semester of the Bachelor's degrees in Engineering

Methodology



First year and first semester of the Bachelor's degrees in Engineering

Continuous summative assessment

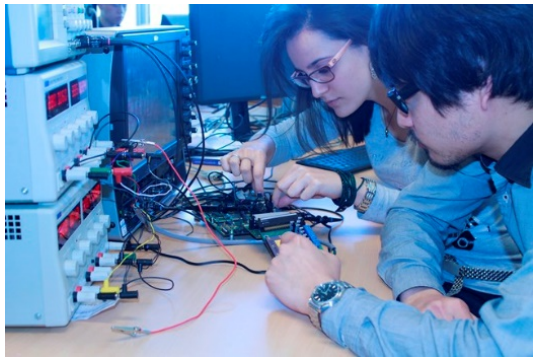
- Each covering a half of the subject content
- In the middle and at the end of the semester (before lectures are over)
- Pass if average score >= 5 out of 10 with a minimum score of 4

Failed?

- Covers the whole course content
- Held in the examination period (after lectures are over)
- Pass if average score >= 5 out of 10

Methodology

Electrical Engineering

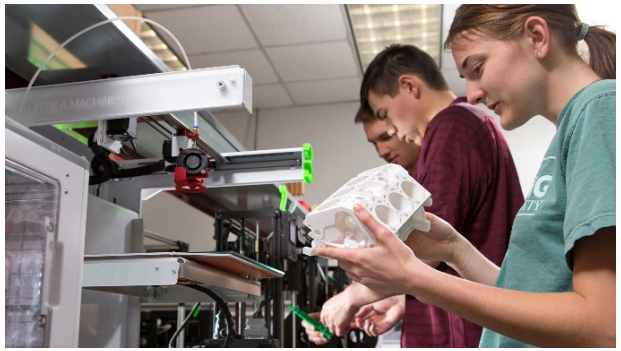


2017/2018

- Size: **33 students** (medium-size group)
- Intensity: **8 team sessions** within the classroom
- Participation: **Compulsory** (students must participate in order to be continuously assessed)

- Size: **79 students** (large group)
- Intensity: **4 team sessions** within the classroom
- Participation: **Voluntary** (students not taking part can be continuously assessed but cannot benefit from group bonuses)

Mechanical Engineering



2018/2019

Methodology

Evaluation: Students' performance + **Student survey**

(small simple size)

Methodology

1. *Indicate your subjective level of involvement in the teamwork* (not involved at all; involved to a lower extent; involved to a considerable extent; very involved from beginning to end)
2. *The teamwork has helped you keep up with the subject* (from 1 to 5)
3. *The teamwork has helped you better understand the contents of the subject* (from 1 to 5)
4. *The teamwork has helped you identify and correct conceptual mistakes* (from 1 to 5)
5. *The teamwork has increased your motivation to face the subject* (from 1 to 5)
6. *The teamwork has made the subject more bearable for you* (from 1 to 5)
7. *Indicate whether you have studied the subject with your group peers outside the classroom* (never; occasionally; sometimes; regularly)
8. *State your opinion about the number of group sessions that have taken place within the classroom* (insufficient; adequate; too many)
9. *Group bonuses have encouraged you to work with your group peers* (from 1 to 5)
10. *State whether you have found useful to have a "Teacher" that can help you clarify doubts about the subject* (from 1 to 5)
11. *State whether you have found helpful to discuss a problem/exercise within your group* (from 1 to 5)

1 → "totally disagree" and 5 → "totally agree"

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Level of involvement

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Perceived usefulness

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Motivation

5. *The teamwork has increased your motivation to face the subject* (from 1 to 5)
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System of incentives

Results

Students' perception of their **level of involvement**

Electrical Engineering		Mechanical Engineering	
Not involved or barely involved	Considerably or very involved	Not involved or barely involved	Considerably or very involved
0	**100**	3.2	**96.8**

		Never	Occasionally	Sometimes	Regularly
Group	**Electrical Engineering**	21.7	30.4	21.7	**26.1**
	Mechanical Engineering	16.1	35.5	41.9	**6.5**

Question 1

A clear overstatement

Question 7

Higher level of involvement by the Electrical Engineering group

Results

Students' motivation

Question 8		Insufficient	Adequate	Too Many
Group	Electrical Engineering	39.1	56.5	4.4
	Mechanical Engineering	22.6	74.2	3.2

	Electrical Engineering		Mechanical Engineering	
Question	Mean	Std	Mean	Std
5	3.96	0.93	3.35	1.05
6	4.13	0.97	3.74	1.18

- A higher degree of engagement by the Electrical Engineering group (with twice as many team sessions!)
- Good overall acceptance
- The larger size of the Mechanical Engineering group made the implementation of the teamwork activities a bit more "chaotic"

Results

Students' perception of usefulness

	Electrical Engineering		Mechanical Engineering	
Question	Mean	Std	Mean	Std
2	3.70	0.82	3.35	1.02
3	3.61	1.03	3.58	0.99
4	3.70	1.02	3.61	0.95
10	3.57	1.16	3.58	1.21
11	**4.26**	0.86	**4.13**	0.76

Students found it quite useful to discuss math problems with their peers

System of incentives

9	**3.96**	0.98	**3.77**	0.99

Group bonuses were also perceived as a motivating factor

Results

Students' attendance and success rates

	Test 1		Test 2		Final Exam		Pass rate
	Attendance	Success	Attendance	Success	Attendance	Success	
Electrical Engineering	100	30.3	78.8	34.6	66.7	30.7	**45.6**
Mechanical Engineering	96.0	23.2	75.0	40.7	51.4	10.8	**26.4**

The implementation of the "Teacher-Apprentice" teamwork activities was much more effective, intense and productive in the small group

Conclusions

1. The cooperative learning of mathematics by engineering students is not only possible, but also effective
2. Giving the students the possibility to discuss a math problem or question with their peers increases their motivation to learn mathematics
3. The cooperative learning of mathematics can fully or largely replace traditional teaching methods and should be at the core of a course for them to be effective
4. Resource demanding
5. Incentives that encourage students to cooperate may increase the effectiveness of cooperative learning methods

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THANK YOU FOR YOUR ATTENTION!

QUESTIONS?

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Outline

1. Background and motivation
2. The “Teacher-Apprentice” group dynamics
3. Methodology
4. Some (preliminary) results
5. Conclusions

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Motivation

- The engineering student is expected to develop competences such as the ability to lead, to work in a team or to present results
- Traditional teaching methods like the master lecture or students' individual work do not facilitate the acquisition of these skills
- How can we *engineer* the learning of mathematics *by engineers*?

Hypothesis: **Cooperative learning**

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The “Teacher-Apprentice” method

- **Overall objective**: *learning by doing*[1] through students’ cooperation in groups
  - ✓ Implement activities both outside and inside the classroom that encourage the students to address math problems in teams

- **Constructive alignment**[1]*:* team skills are to be *develop*ed and, therefore, must be *trained* and *assessed*

[1] BIGGS, J. B. (2011). Teaching for Quality Learning at University: What the Student Does. McGraw-Hill/Society for Research into Higher Education/Open University Press, 2011. ISBN: ISBN 978-0-33-524275-7.

The “Teacher-Apprentice” method

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- It seeks
  - ✓ To strengthen the student's **feeling of responsibility** in relation to their group
  - ✓ To foster that students with lower performance can benefit from the possibility of having a peer with whom they can **clarify doubts**
  - ✓ To facilitate that the students with greater performance can **consolidate their knowledge** about the subject by teaching the rest of their groupmates
  - ✓ A **system of incentives** aligned with the learning of all members of the group via cooperation (but also leaving a bit of room for competitiveness)

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Conclusions

1. The cooperative learning of mathematics by engineering students is highly recommendable and effective
2. Giving the students the possibility to discuss a math problem or question with their peers increases their motivation to learn mathematics
3. The cooperative learning of mathematics can replace classical teaching methods such as master lectures fully or largely
4. Cooperative learning activities should be at the core of a course for them to be effective
5. The effectiveness of the proposed “Teacher-Apprentice” teamwork activity diminishes with the number of teams that the Professor needs to supervise and monitor
6. Designing a system of incentives that encourages students to cooperate may increase the effectiveness of cooperative learning methods
7. Future work: Measures to detect early “drop-out” students and dynamically adjust the groups