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MATHPOL: Development of Mathematical Competencies in Engineering Students using Project-Oriented Learning

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Project Oriented Learning (POL) (1):

Teaching technique:

- development of mathematical competences;
- main objective is the process that leads to learning and not the product itself.

Instructional model that revolves around:

- selected questions and tasks;
- a research process;
- the design of a product;
- knowledge and skills [1].

Project Oriented Learning (POL) (2):

Enables:

- applying technical knowledge to real situations;
- organizing, planning and managing time and resources;
- formulating objectives, goals and purposes to initiate and conclude within determined limits, resources and structures;
- developing critical thinking;
- appreciating the value of information in decision making;
- developing responsibility and innovation capacity;
- achieving a clear awareness of the needs of the country and its regions;
- acquiring the commitment to act as agents of change and respect for the nature;
- acquiring the commitment to work and the willingness to help [2-4].

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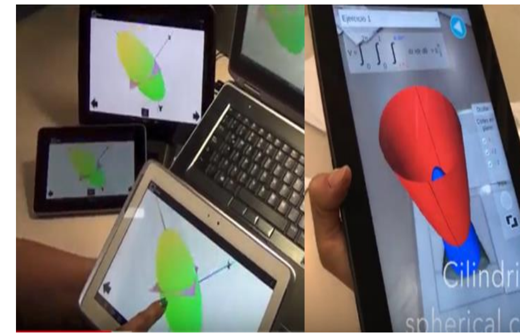
Technological Tools

Two tools that increase spatial skills and develop mathematical skills:

- AVRAM: allows to create, manipulate and visualize geometric models of surfaces in a remote 3D environment;
- ARC: augmented reality cards that allows activities related to Multivariable Calculus.

To obtain the project´s final product:

- 3D printers: printed objects that carry mathematical analysis (description of surfaces, optimization and calculations of centroids, areas and volumes);
- Some of the software used: CalPlot3d, Mathematica and Python.



Design of the projects (1):

Six stages with a total duration of 12 weeks (full course lasts 15 weeks).

Teams of 3 to 5 members.

Professor chooses the theme in advanced:

- real-scale buildings;
- packaging design;
- chess pieces;
- tumor modeling;
- food, etc.

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Design of the projects (2):

- Stage 1. Preliminary design of the object and a box or packaging.
  - Graphing software and tools (AVRAM and ARC) to design objects.
- Stage 2. Mathematical description of the object.
  - Set the parameters using Mathematica or Python;
  - Find the ranges of the variables.
- Stage 3. Print of basic pieces and video making.
  - Allows initial measurements of the mastery level of the competencies.
- Stage 4. Analysis of the surfaces that make the package.
  - Argumentation and use of the language and symbolic operations;
  - Description and mathematical analysis;
  - Mathematical models for intersections, maximum and minimum curves and optimization.

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Design of the projects (3):

- Stage 5. Printing of the 3d model.

  - Comply with all the specifications (scale model, contain a certain amount of liquid, area or volume);

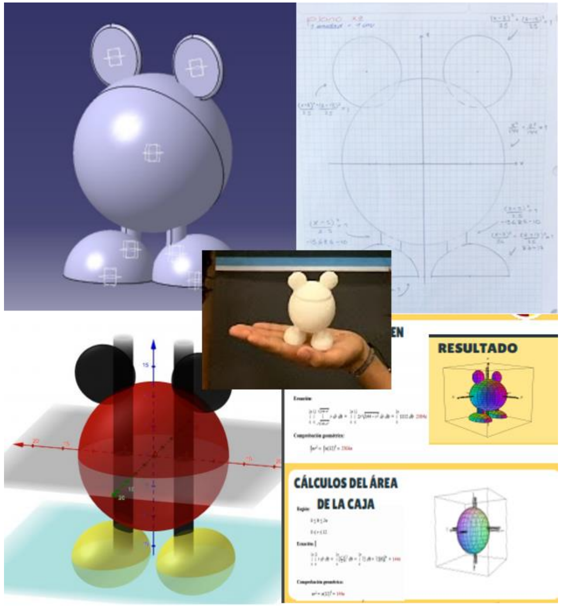
  - Perform calculations and tests;

  - The model and its packaging are adjusted.

- Stage 6. Poster with results.

  - Presentation of the results and final video;

  - Final measurements of the level of proficiency of competencies.



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Results (1):

Pre-test/post-test methodology.

- Impact of the project on the development of mathematical competencies;
- Videos with a specific individual participation and a rubric;
- The rubric evaluated:

- argumentation;
- communication;
- modeling;
- problem solving;
- representation;
- mathematical language;
- use of technological tools.

A 5-step Likert scale was used (total agreement-total disagreement).

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Results (2):

239 students formed N = 60 teams.

A paired analysis of variance with a 95% confidence level.

Means of variables significantly higher in the post-test than in the pre-test (p-value=0).

Competence	Mean Pre-test	Mean Post-test	Confidence Interval 95%	Confidence Interval 95%
Think and Reason	2.517	3.2	(2.300, 2.733)	(2.983, 3.416)
Arguing	2.75	3.417	(2.530, 2.970)	(3.197, 3.636)
Communicate	2.7	3.483	(2.480, 2.920)	(3.264, 3.703)
Modeling	2.783	3.433	(2.564, 3.003)	(3.213, 3.652)
Problem Solving	2.65	3.317	(2.430, 2.870)	(3.097, 3.536)
Representation	2.833	3.467	(2.614, 3.053)	(3.247, 3.686)
Matematical lenguage	2.767	3.517	(2.547, 2.986)	(3.297, 3.736)
Use of technological tools	3.183	4.1	(2.964, 3.403)	(3.880, 4.319)

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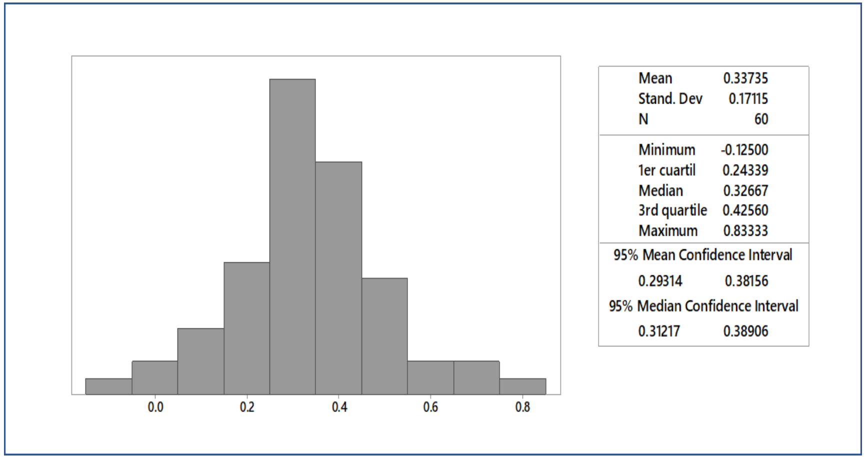
Results (3):

Variables

- *Pre-test grade of student i (Pre_i)*
- *Post-test grade of student i ($Post_i$)*
- *Student learning gain: $G_i = Post_i - Pre_i$;*
- *Student relative learning gain: $g_i = G_i/(100 - Pre_i)$*



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Results (4):

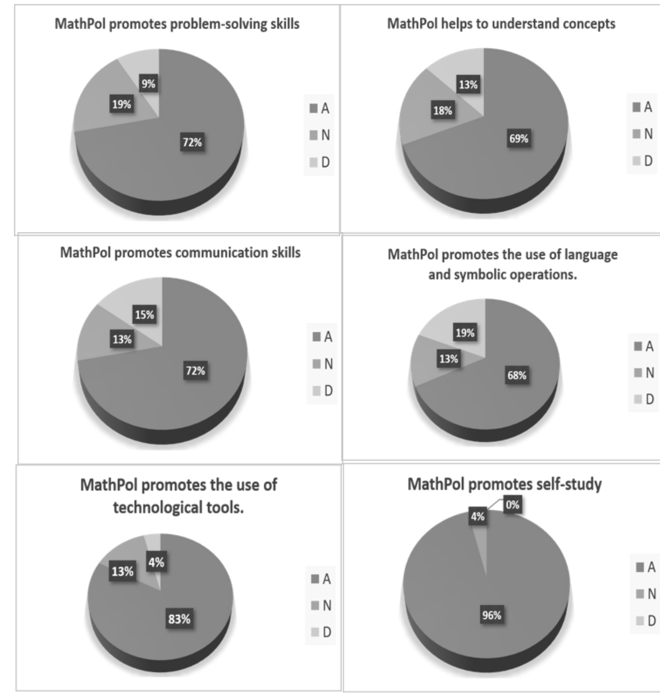
Perception survey on the development of mathematical skills.

- N = 84 responses
- Likert scale with 5 levels (Strongly agree-Strongly disagree)
- Students´responses grouped into three categories:

  - Strongly agree and Agree (A)

  - Neutral (N)

  - Disagree and Strongly disagree (D)



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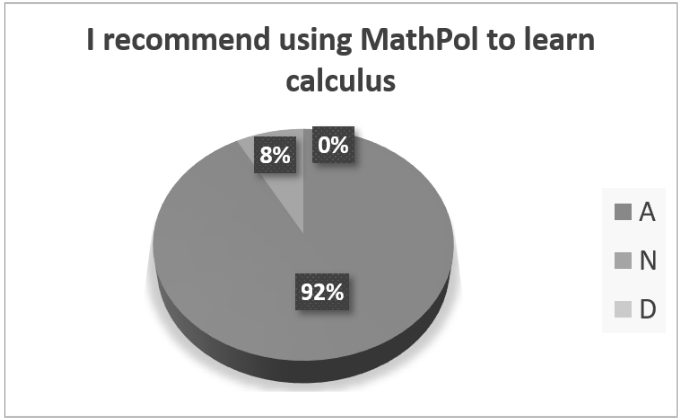
Results (5):

Students

- have a completely active attitude;
- get better results in their final grade;
- 92% of the students totally agree or agree in recommending that teachers continue to use MathPol in calculus classes.



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Conclutions (1):

- Student engagement in a Calculus course;
- Students develop mathematical competencies (thinking and reasoning, argumentation, communication, modeling, posing and solving problems; representation, making use of language and symbolic operations, and use of aids and tools);
- On average, students had a relative increase of 33.7% in the domain of mathematical competencies;
- Technological tools (AVRAM, ARC, CalcPlot3d, and Mathematica) are key parts in the development of mathematical competences;
- Technological tools must be accompanied by pedagogical activities, designed with the purpose of developing mathematical skills.

Conclutions (2):

- Students perceive that
  - the use of MathPol really helped them in their learning process;
  - recommend its use in future generations.
- The improvement in the learning process of Calculus reflected in the average of the final exam
- Success on the use of videos to evaluate the development of mathematical skills.
  - communication and problem-solving skills
  - use of technology and mathematical language.

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Conclutions (3):

Future research includes:

- The use of focus and experimental groups;
- The search for the relationship between spatial visualization and problem solving;
- The use of this methodology in other areas;
- The design and analysis of competencies assessment instruments.

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Thank you for attention!

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