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].
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.
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.
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.
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).
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).

<table>
<thead>
<tr>
<th>Competence</th>
<th>Mean Pre-test</th>
<th>Mean Post-test</th>
<th>Confidence Interval 95%</th>
<th>Confidence Interval 95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Think and Reason</td>
<td>2.517</td>
<td>3.2</td>
<td>(2.300, 2.733)</td>
<td>(2.983, 3.416)</td>
</tr>
<tr>
<td>Arguing</td>
<td>2.75</td>
<td>3.417</td>
<td>(2.530, 2.970)</td>
<td>(3.197, 3.636)</td>
</tr>
<tr>
<td>Communicate</td>
<td>2.7</td>
<td>3.483</td>
<td>(2.480, 2.920)</td>
<td>(3.264, 3.703)</td>
</tr>
<tr>
<td>Modeling</td>
<td>2.783</td>
<td>3.433</td>
<td>(2.564, 3.003)</td>
<td>(3.213, 3.653)</td>
</tr>
<tr>
<td>Problem Solving</td>
<td>2.65</td>
<td>3.317</td>
<td>(2.430, 2.870)</td>
<td>(3.097, 3.536)</td>
</tr>
<tr>
<td>Representation</td>
<td>2.833</td>
<td>3.467</td>
<td>(2.614, 3.053)</td>
<td>(3.247, 3.686)</td>
</tr>
<tr>
<td>Mathematical language</td>
<td>2.767</td>
<td>3.517</td>
<td>(2.547, 2.986)</td>
<td>(3.297, 3.736)</td>
</tr>
<tr>
<td>Use of technological tools</td>
<td>3.183</td>
<td>4.1</td>
<td>(2.964, 3.403)</td>
<td>(3.880, 4.319)</td>
</tr>
</tbody>
</table>
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: $g_i = G_i / (100 - Pre_i)$
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)
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.
Conclusions (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.
Conclusions (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.
Conclusions (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.
References:


Thank you for attention!

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