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GAMIFICATION AS A TEACHING TOOL FOR ANALYTICAL GEOMETRY

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Abstract.
The basic cycle of Engineering courses represents the first barrier for the future engineers. High failure and evasion indices are observed in the first two years of study. The subject Analytical Geometry, in particular, is one of the classes in which students present great difficulty, directly impacting the retention and evasion indices of the course. Creating opportunities for better understanding of contents taught will boost learning and, consequently, contribute for improving academic performance of students majoring in Aeronautic, Mechatronics and Mechanical Engineering at UFU, is the purpose of the project "Active learning as a support element for success in the basic classes in the course of engineering" (PROSSIGA of Analytical Geometry). Among the several learning techniques applied in the Project, it was noted that the use of games associated to teaching favors theoretical improvement besides the interaction among students through work groups. Thus, this study describes the development and application of a group dynamics, intitled "Puzzle", with the main purpose of teaching contents of analytical geometry in an innovative and stimulating manner, through the work of heterogeneous groups, exploring, besides the theory, the abilities of interpersonal relations, leadership and agility of the students.

Keywords: *gamification, engineering, education, teamwork, geometry.*

1. INTRODUCTION

The academic disciplines in the first periods of the Engineering course are the basis for a solid formation, consequently, low performance early in college causes a formation deficiency, which may persist for the entire graduation. It is fundamental to contribute for the improvement of teaching and learning in a continuous and systemic manner; demanding a co-operation with the students immediately after their admittance to the College. Such intervention becomes more important as the contents that, historically, result in greater failure index, are identified. The example of the eighty students admitted to the Engineering majors of FEMEC – Faculdade de Engenharia Mecânica UFU – can be cited, since only 50%, on average, pass the course *Analytical Geometry*.

The project "Active learning as an aid element for the success in basic courses of the Engineering Major" (PROSSIGA of Analytical Geometry) uses several teaching strategies for the reduction of retention and evasion indices in the majors of Mechanical, Mechatronics and Aeronautic Engineering of FEMEC – UFU (Faculdade de Engenharia Mecânica, Universidade Federal de Uberlândia). The Project focuses in creative activities and interaction that promote the learning of Analytical Geometry. Thus, during the first semester 2018, in the selection process for teaching assistants, one of the phases was to develop a different activity schedule, involving the use of dynamics, active methodologies and innovative proposals to be applied complementarily to regular studies, resulting in students' approval.

Among the dynamics presented during the selection process, one chosen by the coordination of the Project to be tested was the activity entitled *"Puzzle"* due to its innovative and integrative aspect. The purpose of the activity is, not only approval in the subject through the solution of complex problems of analytical geometry, but also the integration of the students, promoting the development of team work abilities, leadership and organization of time.

Thus, the designed group dynamics fits in the teaching technique of gamification. This term consists, in synthesis, in the use of principles and concepts of games in an environment different from games. According to Werbach and Hunter (2012), the idea originated in 2002 with the programmer Nick Pelling in an online design environment. Gamification became popular, however, only in the last decade. Several books were published about the theme, such as Werbach and Hunter's "For the win- How game thinking can revolutionize your business", published by *Wharton University of Pennsylvania,* and McGonigal's "Reality is Broken: Why games make us better and how they can change the world",

presenting gamification for both education and marketing. However, gamification has been based on online games to develop the teaching methods, according to Marcelo Luíz Fardo (2011), who did both the Master and Doctorate in the area of gamification at UCS. In contrast, the in the proposition of the Puzzle, the principles of a physical game were used together with the active teaching method.

The active teaching method favors student's autonomy, rises his curiosity and stimulates decision taking (Borges, 2014). And the combination of this method with gamification results in an intensification of teamwork, promoting integration of the group, leading the students themselves to understand and fix the subject presented in the classroom, all in a relaxed and informal environment, which allows the results to appear naturally.

The name Puzzle was considered due to the similarities with that game and for believing that some of the fundaments and techniques needed to solve a puzzle are fundamental parts for teaching at any level. Puzzle games allowed the construction of the cognitive reasoning, teaching contextualized contents and the respect and the valorization of all parts involved, since for the assembly of the puzzle all parts must be used (Nascimento, 2011). Moreover, the dynamics also stimulates the communication among the students and the development of work as a group, considering that the students are led to propose the question in the group and, subsequently, to solve it together. In order to complement the benefits of the dynamics, the groups are formed randomly, assuring heterogeneous groups, stimulating the contact among different students of different majors of FEMEC.

Also, assembling a puzzle stimulates the brain, developing cognitive abilities and increasing reasoning, promoting and enabling learning of new knowledge. Moreover, it is good for the memory, developing motor coordination, fostering perception and increasing focus, as well as causing social interaction, when done in groups. Thus, joining the process of assembling a puzzle with the resolution of an analytical geometry exercise before exams, represents an instigating and attractive challenge for the students.

It is possible to find applications for the dynamics "Puzzle"; however, the conceptions and objectives are different. Usually, the dynamics of assembling a puzzle in groups aims at stimulating the union among the participants, performing only as an integrative activity. The pedagogue Érika Poeys used conventional puzzles as a tool to integrate a group of teachers under her responsibility (Poeys, 2007). In contrast, professor Quénia Damata looked for stimulating class attendance in a religious group and, at the same time unite the group by assembling a puzzle (Damata, 2014).- These examples helped foster and justify the efficacy of using a puzzle for the formation and union of a group of people, promoting the integration between students of FEMEC; however, in the project, the game is used mainly as a tool for teaching proposing problems about the contents of analytical geometry.

The activity Puzzle was done for the first time in first semester 2018 at the Universidade Federal de Uberlândia for the students majoring in Mechanical, Mechatronics and Aeronautic Engineering, as a content review for the second exam of analytical geometry. The activity represents and complementary study manner for the evaluation. The dynamics and the results obtained are presented as a reference and to stimulate broader use of active and alternative teaching practices.

2. DEVELOPMENT

The dynamics passed through a creative process, being subjected to changes to the first version until it reached the form that was applied to the students. The initial conception looked especially into the setting the pillars of the activity that would integrate agility, teamwork, knowledge and strategy. Due to the similarity of competences of assembling a puzzle and the objectives of the dynamics, the connection was observed and demonstrated by the name of the activity.

The dynamics, in its final version, was planned in such a way that the problems of analytical geometry would be printed in paper and cut into pieces, making the pieces of a puzzle. Each student receives a piece representing part of the formulation of a problem that only can be solved after all the parts are gathered together.

The game consists of two stages: the first one is eliminatory, while the second one is the final phase, defining the winning couple of the round. Groups of 4 people are formed in the first stage, using the pieces that are distributed assuring the formation of heterogeneous groups, formed by students of the three courses, promoting the socialization expected of the activity and also the exchange of information, since the students have different professors for the subject. Figures 1 and 2 depicts students divided into groups for the first round of the activity, working as teams to solve the proposed problems.

Figure 1: One group of students solving the puzzle question.

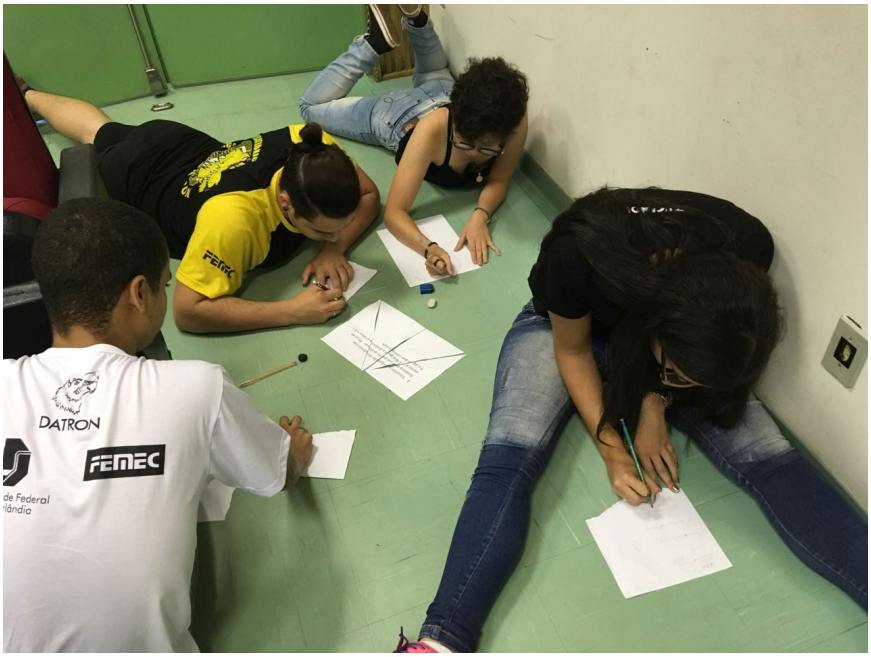

Figure 2: A second group of students solving a puzzle question.

Thus, the puzzle parts are shuffled and displayed on a central table, in such a way that no one can visually solve it. It is fundamental that the same formulation be present at least twice since, for a fair competition, time can be compared only between groups solving the same challenge. However, it must have more than one formulation, so more than one group can advance to the final stage. The competition starts as soon as each student has a piece of the puzzle at hand.

The first challenge is to find the rest of the group by assembling the puzzle that leads to the formulation of the problem. The group solving this stage in less time has an advantage in the game. After assembling the formulation, the second challenge is solving the analytical geometry problem as quickly as possible to assure a slot in the final.

Similarly to the first stage, the formulation is cut in different manners, making each one unique. The pieces of the new puzzle are shuffled and displayed on the table, where the 12 finalist students solve the same problem, working as 6 couples. Again, each student will get one part of the puzzle and, at the count down, start the first challenge, which is finding, among the other 11 participants, the only piece that complements the formulation of the problem. The first couple to correctly solve the problem is the winner of the challenge. It is important to note that all questions are solved and discussed in detail with all the participants after each stage, intensifying the review work of the topics.

The first edition of the Puzzle had the participation of 24 students, from which 17 were from Mechanical, 3 from Mechatronic and 5 from Aeronautic Engineering. However, in Figure 3, there are only 22 students, thus, 2 of them had already left the event. Certainly, the dynamics depends on the number of participants, and adjustments on the size of the groups and the number of rounds may be required.

Figure 3: Participants of the puzzle and Teaching Assistants of the PROSSIGA project.

In order to ensure the coherence between the puzzle activity and the contents that the students were learning during regular lectures, the professor of Mechanical Engineering provided the questions encompassing the contents for the Exams for Mechanical, Aeronautical and Mechatronic Engineering. The questions are listed below.

First Question

In geometry, the median of a triangle is the segment of a straight line connecting a vertex of that triangle to medium point of the opposite side of that vertex. Using the concepts of vectors and straight lines, determine the equation symmetrical of that line and the length of the median AM of the triangle A B C (3, 1,4), (2,4,5) and (0, 1,1).

Second Question

Find the equation of the plan that contain the line $r = \begin{cases} x + y - z + 3 = 0 \\ x - y + 2z + 5 = 0 \end{cases}$ and is parallel to the x-axis.

Third Question

Determine the deneral equation of the plan that contain the point A(1,2,1) and the line that is defined by the intersection of the plan $\pi: x - 2y + z - 3 = 0$ with the plan y z 0 .

Fourth Question

Find the equation of the conic whose distance from a random point P (x, y) to the point A (-2, 3) is equal the distance to the line $x + 6 = 0$.

3. RESULTS

After concluding the activity, it was made an analysis of the scores of the students that participated at the activity and of the ones that didn't. For those who participated, the analysis covered the exam that occurred after the Puzzle, and the one before, so a comparison could be made between the average scores of both exams. However, for those who didn't participate of the activity, the analysis covered just the second exam, that was after the Puzzle, so a comparison between their scores and the scores of the participants could be made.

At first, Figure 4 shows the performance of the students in the second exam of analytical geometry, taken after the dynamics. It can be seen that the students who took part of this dynamics had a much greater average performance than those that did not. And Table 1 shows the number of participants and non participants students together with their average score at the second exam.

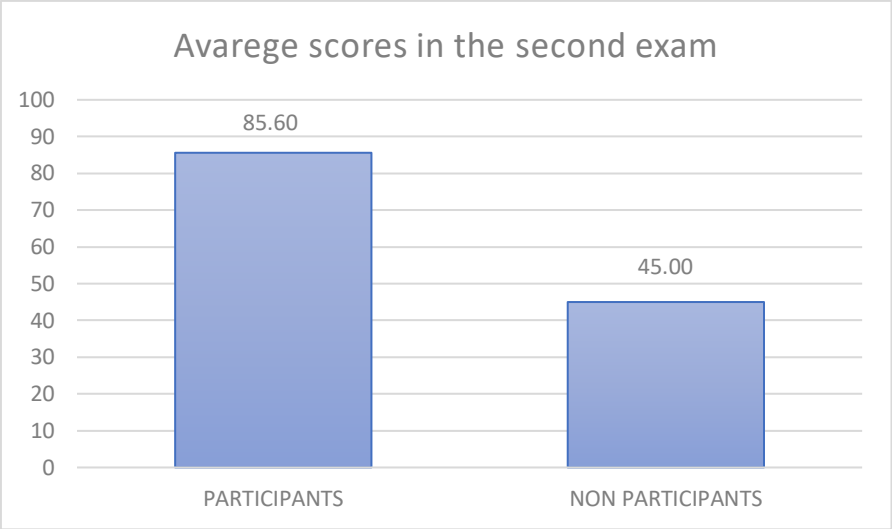

Figure 4. Average scores of the second exam of the students that participated or did not participated of the proposed activity.

Table 1. Experimental results for the execution of the activity.

	Number	Average score
Participants	24	85.6
Non participants	54	45.0

Furthermore, in Figure 5 it can be seen the comparison between the average score of the participant student at the first exam and the second exam. Noting that the Puzzle it self was given just before the second exam, and not before the first.

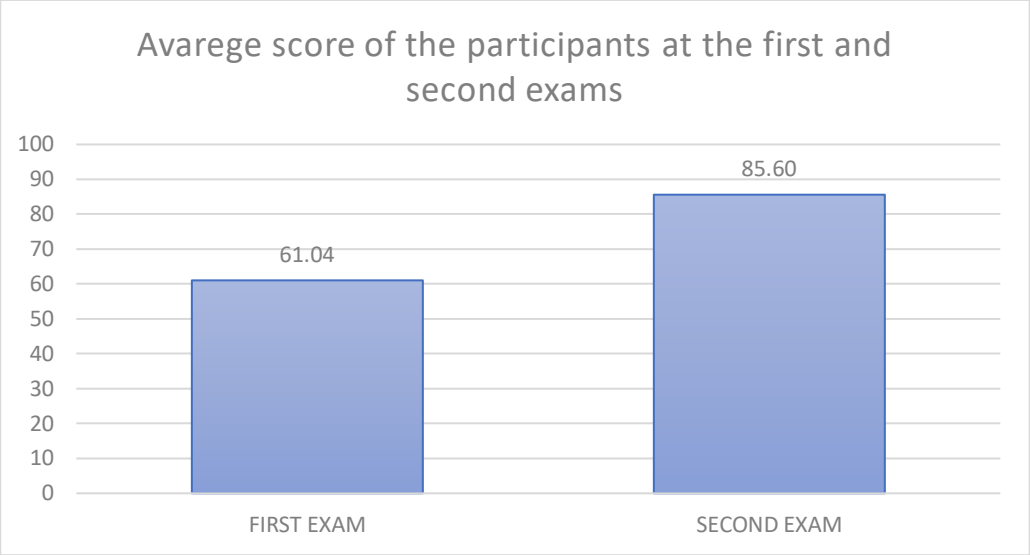

Figure 5. Average scores of the first and second exams of the students that participated of the proposed activity.

Also, one other result that was obtained by the activity was the testimonial of some students that participated of it. Bellow there are two examples of testimonials, the first one from Marcus Henrique de Almeida Filho (student of Mechanical Engineering), and the second one from Arthur Reis Bello (student of Mechatronic Engineering).

"I participated in the Prossiga Project in 2018-1 and today I realize that it was very important to me. At the Puzzle event I was the winner along with a friend. This event approached the Analytical Geometry discipline in a different way from the conventional one. So, the students were able to learn in a fun way, with the 'adrenaline' of competition, which I think is a very good way of learning.

Also, the cool thing was not even learning the discipline, but the integration between people from three different courses. As a newcomer, integration becomes very necessary early in College, as making friends is essential to performing well in college."

"The puzzle was very good especially for training to develop the exercises under the pressure of a competition, which ends up matching with my difficulty in most of the tests: finish it on time. Another thing that I really liked was the contact I made with the mechanics students, because, in my first period, I had more contact with the Mechatronics and the Aeronautics students who had classes with me, rarely with the mechanics. It turned out that the first friendships I made in the mechanics were made in the puzzle.".

4. CONCLUSIONS

It can be perceived that the activity had a positive impact on the grades obtained by the participants in the dynamics "Puzzle", providing evidence that investing in active methodologies can represent a great leap in Higher Education, which could also be a success in courses of science and technology. The game develops a series of abilities and aids in the study and understanding of complex exercises of Analytical Geometry. The students learned through a healthy competition that also allowed them to create bonds of friendship or, at least, to meet other students in a crucial moment, such as the beginning of their college education.

As it can be seen in the results, the scores of the students that participated of the activity are considerably higher than their scores at the exam that didn't count with the Puzzle, and also higher, at the second exam, than the scores of the students that didn't participate of the activity. That numerical analysis proves the benefits that the Puzzle brings for the Analytical Geometry subject. In addiction to this the testimonials evidence the benefits to the students' personal relationship with one each other.

In summary, the dynamics reached its main objectives: stimulation socialization and teaching Analytical Geometry, confirming the qualities of gamification for education, expanding it to Higher Education and also confirming the idea of the authors that joining group work with the game puzzle and gamification in the context of University education represents a rewarding teaching technique for all involved. The next step will be promoting and applying the dynamics in other coursed of engineering to maximize the potential of the activity and confirm that the dynamics is an excellent teaching tool.

5. ACKNOWLEDGEMENTS

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