The Skills Stimulated by Integrating Contents of Production Management in Higher Education in Engineering by Adapting 'The Paper Airplane Factory' Game

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Abstract. *The professional of the future needs to have a set of behavioral (soft) and technical (hard) skills, but traditional teaching prioritizes hard skills. This article sets out to promote the integration of production management subject content into higher education in the field of engineering by adapting the game called "The Paper Airplane Factory", and understand which skills were stimulated by the game in the perception of the students involved. As result, the game was shown to be suitable for contributing towards developing the skills and competencies of future engineers, such as: (1) analytical thinking and innovation, (2) active learning and learning strategies, (3) critical thinking and analysis, (4) creativity, originality and initiative and (5) leadership and social influence, of which four are considered soft skills.*

Keywords— *higher education, skills, hard, soft.*

1. Introduction

In an increasingly competitive labor market, every professional has to be aware of the trends and needs of this market, and to adapt themselves to different realities. Hence, soft skills and competencies, such as emotional intelligence, creativity, innovation and leadership, are gaining prominence [World Economic Forum - WEF 2020]. Considering this evolution, art.3 of Resolution nº2, of April 24, 2019, which established the National Curriculum Guidelines for the Undergraduate Course in Engineering, lays down that the profile of graduates who have completed an undergraduate course in Engineering must include, among other features, the following characteristics: the graduate (a) has a holistic and humanist vision, is critical, reflective, creative, cooperative and ethical and has a strong technical background; (b) is able to research, develop, adapt and use new technologies, with innovative and entrepreneurial action; (c) is able to recognize the needs of users, formulate, analyze and creatively solve Engineering problems; (d) adopts multidisciplinary and transdisciplinary perspectives in his/her practice; (e) considers global, political, economic, social, environmental, cultural and occupational safety and health aspects; (f) acts with impartiality and commitment to social responsibility and sustainable development.

This resolution highlights the importance of developing soft skills. However, traditional teaching techniques primarily develop hard skills and competencies. Thus, innovation in pedagogical practices is a fashionable theme and gamification emerges as a potential format [Palomino et al. 2023]. The gamification process in education boils down to the elements applied to the learning program. Gamification is the addition of game elements, also called game mechanics, in non-game settings. Game mechanics can be classified [Huang and Soman 2013]: Self-elements that can be points, badges of achievement, levels or simply time restrictions. These elements make students focus on competing with each other and on recognizing self-fulfillment; and Social-elements that are interactive competition or cooperation, such as leaderboards. These elements place students in a community with other students and their progress and achievements are publicized.

Thus, Santos and Koscianski (2015) proposed the game 'The Paper Airplane Factory' for teaching administrative functions. The challenge was to define any simple and repetitive task, which could be done in a group or in the classroom, of a playful and engaging nature, in which students applied the concepts of planning and control in administration. For this, five steps were followed: (1) to become familiar with the target audience and context; (2) to define learning objectives; (3) to structure the experience; (4) to identify resources; (5) to apply gamification elements [Huang and Soman 2013; Santos and Koscianski 2015]. In this paper, the same procedure was followed, but the scope was modified to cover a greater number of discipline contents. Therefore, this article sets out to promote the integration of production management subject content, by adapting the Paper Airplane Factory, into higher education in the field of engineering.

In addition to this introduction, the paper is organised as follows. Section 2 brings a theoretical background. Section 3 presents the methodology and the proposed game procedure. Results and discussions are presented in Section 4, and finally, in Section 5, conclusions are made.

2. Background

Professional performance is the result of a set of “abilities”, “competencies” or “forms of dexterity” (from the word “skill”), which can be acquired by means of academic training and personal experiences of the individual, divided into behavioral skills (soft skills) and techniques (hard skills) [Fleury and Fleury 2004; García-Aracil et al. 2021].

Hard skills are skills which are considered to be technical, which are acquired by means of some professional or university training, courses or from acquired experiences and are easily measured, as they are proven in the curriculum with certificates or diplomas [Mailool et al. 2020; Sopa et al. 2020]. Thus, they can be developed within the classroom during professional training or within the work environment.

On the other hand, soft skills are known as transversal skills, initially designated as "key competences", and refer to skills that are not directly related to academic training or technical qualifications performed by a person [García-Aracil et al. 2021]. In this context, soft skills are those directly linked to aptitudes acquired over the course of life and experiences, whether professional or not, but which are part of the individual's behavior. In addition to interpersonal and social characteristics, soft skills are also personal qualities of individuals that change the way they carry out their professional activities. These skills may already be characteristics present in the individual and/or be learned through education, experiences and training [Sharma, 2018].

The competences required in the labor market are directly related to social and technological transformations. Studies point to changes in the skills required in all areas, principally due to the 4th Industrial Revolution, which brings factors such as the era of advanced robotics, the development of artificial intelligence technologies, automation in the transport sector and machine learning [Volpe et al. 2017; WEF 2016]. Hence, the WEF (2020) re-elaborated a report highlighting the 15 skills expected for 2025 in the workplace, classified here as soft and hard (Table 1).

Table 1. Skills of the future classified into *soft* and *hard*

Code	Description	Type of skill
a	Analytical thinking and innovation	Soft
b	Active learning and learning strategies	Soft
c	Solving complex problems	Hard
d	Critical thinking and analysis	Hard
e	Creativity, originality and initiative	Soft
f	Leadership and social influence	Soft
g	Use, monitoring and control of technology	Hard
h	Technology design and programming of technology	Hard
i	Resilience, tolerance of stress and flexibility	Soft
j	Reasoning, problem solving and ideation	Hard
k	Emotional intelligence	Soft
l	Troubleshooting and User/Customer Experience	Soft
m	Orientation towards serving (Actively look for ways to help others)	Soft
n	Systems analysis and evaluation	Hard
o	Persuasion and Negotiation	Soft

Source: Adapted from WEF (2020).

If one understands a university as the laboratory where these skills are developed, it is essential to rethink the pedagogical practices used, in order to adapt to emerging changes and to develop the skills that future professionals will need [Alves et al. 2016; de Oliveira and de Almeida Jr. 2015].

3. Methodology

The development of the game followed the same methodology as Santos and Koscianski (2015). Thus, Higher Education students in engineering course who have the subject of Production Management, or similar, in their curriculum are the target audience. The context involves the need to make the theory 'tangible', by engaging in gamified practice. The objective of learning was to integrate several concepts studied separately during the course, which are: product design, work design (work method and measurement), capacity planning, design of layout and associated quality concepts. The experience was structured in three milestones: the organization of the teams, the execution of actions, and the control process, i.e., how the teams dealt with the uncertainties. The resources needed are easily accessible, such as sheets of paper, timers, pencils and calculator. Finally, the gamification elements identified were: the competition between the teams and the time restriction in certain stages.

3.1. Game procedure

The studies developed by Corrêa (2022), Guerrini (2019), Moreira (2014), Slack et al. (2015), and Venanzi and da Silva (2013) were considered to define the game procedure.

Students must be subdivided into teams, composed of three to six members, and must perform the steps outlined in Figure 1.

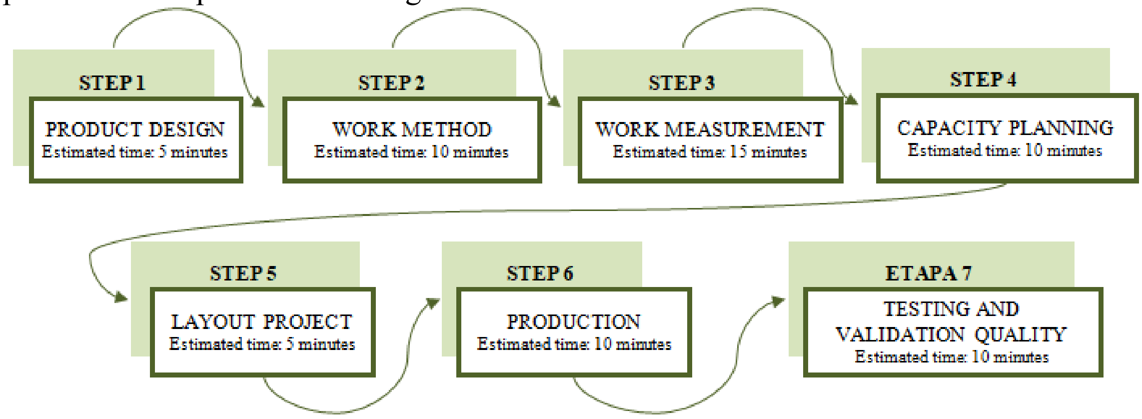


Figure 1. Steps of the game of the paper airplane factory adapted

Source: the authors (2023).

The first step is to address the syllabus on **product design**. If this topic is not part of the syllabus of the subject, this will not compromise the proposed dynamic. Here, students receive a sheet of paper per team (preferably a notebook) to make the origami. In this game, a paper airplane was chosen, but may involve other forms of origami. Thus, each team will develop a “model” of an airplane, i.e., their design of the product. The requirements for the process and for the client must be defined by the teacher. Here, two requirements were imposed: (1) the process requires the insertion of three designs, such as a window, a logo, a door, etc.; and (2) the client requires the plane to have the ability to fly from one corner of the classroom to the other.

With the model defined, the second step will address the study of the **work method**. Each team must divide the task of building the plane into elements, i.e., each fold, or design carried out, will correspond to one element.

In the **work measurement** step, each team must group the elements described in step 2 into at least three workstations (P1, P2 and P3). This aggregation is not mandatory, but it is interesting due to the degree of simplicity of the elements. Thereafter, they should start timing the work done by each work point. For the timing activity, the need for five identical planes (n=5) was established, as per the design of the project. Thus, the timing of the process makes it possible to calculate the standard time (ST) of the operation, i.e., the total time required for producing one paper airplane unit. In order to simulate the relationship between the research & development (R&D) Department and the Production Department, each team can be offered sheets of paper that are different from the one used in the product design stage, thus requiring a possible adaptation of the process or "raw material" to follow such as the blueprint.

With regard to the standard time (ST) calculated in step 3, the game moves on to the **capacity planning** step. The teams must calculate, according to the methodology of Peinado & Graem (2007): a) Installed capacity, (b) Available capacity, (c) Degree of availability, (d) Effective capacity, (e) Degree of use, (f) Realized capacity, and (g) Efficiency index. For this step to be implemented, the teacher must delimit the number of workers, the length of the working day and the downtime.

Going on to the fifth step, **layout design**, teams must organize themselves, and form a flow of production suitable for mass production. Let them organize themselves, reminding them of the jobs already delimited. As a technique here, the production line balancing must be done, in which the number of employees, or workstation(s), must be determined. Here the cycle time (CT) will be calculated by the ratio between the available time in the period and the required amount of production in the same period. The actual number of workstations must consider the proposed layout.

In the sixth step, **production** must be started. In order for everyone on the team to participate, the members must divide themselves between the workstations and position themselves in order to form a production line, as per the designed layout. The teams will receive the same number of sheets of paper (here, it is also recommended that a different type from steps 1 and 3 be used). In this step, it is fundamental to determine an execution time and to time it. By doing so, it will be possible to verify which team will be able to produce most within that time. Finally, **testing and validating quality** are carried out. The winning team will be the one that produces the greatest number of planes within the project's specifications and the customer's requirements.

3.2. Evaluation of the game

To evaluate the game developed, a structured self-administration questionnaire was drawn up. The questionnaire was sent, via Google forms, to the students who participated in the game, shortly after they completed their experience in the classroom. Students' feedback acts as an important trigger for changes in the quality of teaching and consequent professional development [Kalin and Steh 2015]. Participation was voluntary and the respondent's anonymity was guaranteed. The questionnaire consisted of questions specific to the game developed (see below), for which answers were binary (yes or no):

- ✓ Was the game able to aggregate the different contents of the discipline?
- ✓ Did the game help to better understand the content covered?
- ✓ Was the game fun?
- ✓ Do you know what the "skills of the future", listed by the World Economic Forum, are?

In addition to these, considering the 15 skills summarized in Table 1, the following questions were asked:

- ✓ Do you believe that your undergraduate course, with only the experience in a traditional classroom, develops the following skills?
- ✓ Do you believe that new teaching methodologies, such as gamification, can develop the following skills?
- ✓ Regarding the Paper Airplane Factory game, what skills do you believe it helped to stimulate/develop?

The answers to these questions were made using a 5-point Likert scale: (5) strongly agree to (1) strongly disagree.

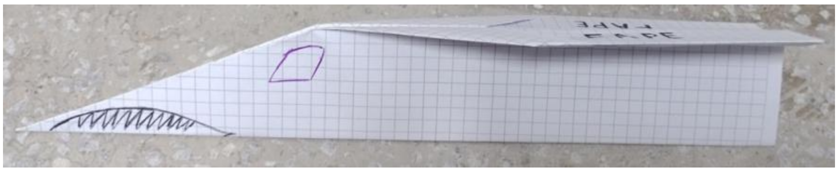
4. Results and Discussion

This section will be divided between the execution of the game, applied in class 2022.2 of the subject of Production Engineering of the Department of Mechanical

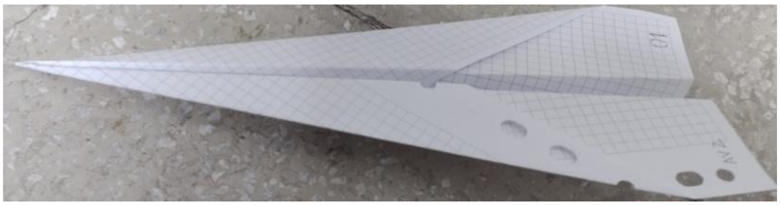
Engineering (DEMEC) at the Federal University of Pernambuco (UFPE), and the evaluation of it made by the students.

4.1. Playing the game

Two teams were formed with six members each. For the first stage, a notebook sheet was provided to the teams. The blueprint developed by the Boeing and Embraer teams (so named by the students themselves) is shown in Figure 2.



(a)



(b)

Figure 2. Blueprint of the product: (a) Boeing and (b) Embraer

Then the teams defined the work methods. The Boeing team opted for just describing them, and established the work method in eleven elements. An interesting fact was that the Boeing team chose to remove the part of the sheet with the punched holes (element 0 - cut sheet). The Embraer team preferred to draw the work methods into six elements.

For step 3, the grouping of elements, forming larger elements was left as an optional action. Moreover, teams received sheets without punched holes. Thus, the Boeing team eliminated element 0 and grouped the elements into three work stations, while the Embraer team kept all the elements, grouping only the last two. The timing performed by the teams is presented in Table 2. To calculate the standard time (ST) a pace factor $f_r = 90\%$ was considered for all elements and a tolerance factor TF=15% for all teams.

An important fact that happened was that the Boeing team opted for only one member to fully produce the plane and the five units, with another member responsible for all the timings. On the other hand, the Embraer team opted for each member to make a complete plane (*n*=5), and the sixth member timed the others' execution times. At the end, there was discussion on these strategies, because:

- ✓ The Boeing team created a bias in the times since the same member who designed the plane was the one who executed the other 5 units. This skill may not represent the team's real time, since the others did not perform any of the production steps;
- ✓ The Embraer team, on the other hand, started with a member who did not pay attention to the details of the design and substantially increased the time (*n*=1).

Table 2. Stopwatch Times and Standard Time

Work station (WS)	*Elements (E)*	*Stopwatch time (seconds)*					*Basic Time*	*Standard Time*
BOEING		*n=1*	*n=2*	*n=3*	*n=4*	*n=5*	$BT_i = t_m \times f_r$	ST $=(\sum_{i=1}^{5} BT_i) \times$ TF
WS1	E1, E2, E3 and E4	48.00	45.44	41.48	31.08	46.00	38.35	104.04
WS2	E5, E6 and E7	28.75	28.50	21.02	26.00	21.00	25.09	
WS3	E8, E9 and E10	41.00	29.00	26.09	28.00	25.25	27.03	
EMBRAER		*n=1*	*n=2*	*n=3*	*n=4*	*n=5*	$BT_i = t_m \times f_r$	ST $=(\sum_{i=1}^{5} BT_i) \times$ TF
WS1	E1	40.00	25.00	26.00	25.00	33.00	26.82	89.11
WS2	E2	20.00	15.00	14.00	16.00	10.00	13.50	
WS3	E3	21,50	14.00	13.00	22.00	16.00	15.57	
WS4	E4	7.00	8.00	7.00	6.00	4.00	5.76	
WS5	E5 and E6	21.00	21.00	16.00	17.00	13.00	15.84	

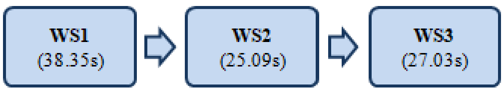
For step 4, the teams were asked, first of all, to consider the existence of only one employee and the workday given by an 8-hour shift, 5 days a week. The teams were then able to scale the capacity using the ST in Table 2. Discussions about maximum and minimum production were encouraged.

Subsequently, the layout design consisted of production line balancing. For this, the dimensioning of the workforce needed was requested, by means of the theoretical and actual number of jobs. Here, three daily production scenarios were established for simulation. Considering 8 hours per day and a tolerance factor of 15%, there are 408 minutes of work/day, generating a cycle time observed in Table 3 for both teams. Given the times of the WS of each team, Figure 3, the theoretical number (TN) and real number (RN) of jobs can be calculated.

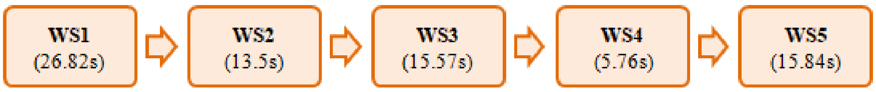
Table 3. Production line balancing

Scenarios		Boeing		Embraer	
Units per day	Cycle Time (CT)*	TN	RN	TN	RN
480	51.0s	1.77 ≈ 2	3	1.519 ≈ 2	2
800	30.6s	2.956 ≈ 3	4	2.532 ≈ 3	3
1500	16.32s	5,543 ≈ 6	7	4.748 ≈ 5	5**

* Given demand, in units per day, CT is the time available to produce one unit.
** If one employee is able to work both on WS1 and WS4, otherwise 6 employees will be needed.



(a)



(b)

Figure 3 Layout of the production line: (a) Boeing and (b) Embraer

Observing the values in Table 3, in all cases the Boeing team had to adjust the actual number of jobs. This is because the time of one or more elements exceeds the available CT. Example: WS1 = 38.35s, with CT of 30.6s, two workers will be needed.

In theory, we cannot assume that a worker who is in WS2 or WS3 will be able to help. In practice, these particularities can be verified.

In the **production** step, 17 sheets of A4 bond paper were given to each team. Again, sheets of a different type were used to see how they would cope with the change. In this case, the teams did not present difficulties. They were asked to position themselves on the production line, so that everyone could execute elements. The Boeing team decided to divide its six members into two parallel production lines, while Embraer placed the sixth member in WS1 as it was the line's bottleneck. At first, the Boeing company seemed to gain experience and improve on pre-calculated times. However, at a given moment, one of the lines ran out of material in WS3 (pencil graphite used for the drawn details). This generated accumulation of units in WS2. Consequently, the team produced 8 units less than the Embraer team. In the test phase, the teams threw their planes from one side of the room to the other, which became a moment of relaxation. Obviously, even with some frustrated flights, the Embraer team won the challenge.

4.2. Evaluation of the game and the skills stimulated

Nine responses were obtained and, therefore, only a descriptive analysis will be performed here. All agreed that the game was able to aggregate the different contents of the discipline (1 agree and 8 totally agree), thereby helping to better understand the contents covered (3 agree and 6 totally agree). Seven students totally agree that the game was fun, 1 agreed and only 1 student neither agreed nor disagreed. Only two claimed to know what the "skills of the future" are.

Observing the data in Table 4, it can be stated that, in the opinion of the students, traditional teaching does not develop skills as much as new teaching methodologies such as gamification.

Table 4. Number of answers by skill

Do you believe that your undergraduate course, only with experiencing a traditional classroom develops the following skills?															
	a	b	C	d	e	F	g	h	i	j	k	L	m	n	o
I totally disagree	3	4	1	3	3	5	2	4	6	2	7	5	6	3	8
I disagree	3	4	1	3	3	2	3	2		3	1	3	3		1
I neither agree nor disagree	1		2			2	3	2	1		1	1		2	
I agree	2	1	5	3	3		1	1	1	4				4	
I totally agree									1						
Do you believe that new teaching methodologies, such as gamification, can develop the following skills?															
	a	b	C	d	e	F	g	h	i	j	k	L	m	N	o
I totally disagree											1	1			1
I disagree															
I neither agree nor disagree		1	1			2			3		2	2	2	1	2
I agree	2	7	5	5	6	5	8	8	5	7	5	4	5	5	3
I totally agree	7	1	3	4	3	2	1	1	1	2	1	2	2	3	3
Skills stimulated by game	7	6	1	6	7	5	0	1	1	7	0	2	1	5	3

In relation specifically to the proposed game, Table 4 shows that of the five most stimulated skills in students’ opinion, four are considered soft (a, b, e and f) and one hard (d). The students' feedback reinforced the importance of developing new ways of teaching and learning in higher education, especially in Engineering.

5. Conclusion

The game developed was able to fulfill its objective. The main skills Stimulated by the game, according to the students, were: (a) Analytical thinking and innovation, (b) Active learning and learning strategies, (d) Critical thinking and analysis, (e) Creativity, originality and initiative and (f)) Leadership and social influence, of which four are considered soft skills.

However, some points deserve discussion and improvement. First, the game was developed during the semester and, thus, the steps were applied in four days, following the content addressed. Although some students like this division, as there is already a link with the content, others consider it bad to develop some activities when the team is not complete, due to the absence of members. This is an important result to evaluate the ideal moment to use the game. The students also suggested *"compiling a short document explaining the project tasks before classes, as much of the project time was spent explaining how the activities would be performed*". In addition, they suggested improvement through *"scores based on pillars (e.g., design, lead time, etc.).*

As to future lines of research, the aim will be to enhance the method, considering the suggestions, and having applied it applied in new classes, in order to increase the number of students reached and, consequently, responses to the questionnaire. Thus, in the end, it will be possible to understand if there really is a statistical difference between the skills Stimulated, according to the students' opinion.

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