Research Article

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DrIVE-MATH Project: Case Study from the Polytechnic of Porto, PT

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Abstract: The School of Engineering of the Polytechnic of Porto (ISEP) has embraced the DrIVE-MATH project, since September 2017. Active-learning (AL) techniques were implemented in several Math courses, namely Linear Algebra and Analytic Geometry, Probability and Statistics, Statistical Models, Computational Mathematics, and Differential and Integral Calculus I. In this paper, we will share the strengths, weaknesses, opportunities and threats of the implementation of the active-learning (AL) environment in these courses. We will detail the courses' plans, emphasizing the syllabus, pedagogical methodologies, assessment methods, students' perceptions, and other related issues. Several questionnaires were posed to the students enrolled in these Math courses during the last three academic years. The statistical analysis of the gathered data provided valuable indications of students' perceptions on the effectiveness of several AL methods, on the development of their own essential (soft+hard) skills. These skills will be a valuable resource to their future professional and personal lives. The 5th Industrial Revolution is just around the corner.

Keywords: DrIVE-MATH, active-learning, eduScrum, Agile education

1 Introduction

Education institutions (EIs) are challenged to discuss the inexorable structural transformations imposed nowadays. EIs are behest to cope with the increasingly demands, emerging from the Fourth and Fifth Industrial Revolutions. In such an extraordinary moment of societal shifts, and even now facing the COVID-19 pandemic, EIs are expected

to raise at the quest, and promote novel educational models. These models need to consider lifelong learning, as a means to subsist to and manage the technological breakthroughs. Moreover, HEIs should also focus on developing essential skills, such as higher critical-thinking, better communication skills, improved collaboration, problem-solving, motivation, among others, to help students build a successful future professional life. The active-learning (AL) methods are believed to help developing these skills [63, 47].

Higher Education institutions (HEIs) are at the front row to make and promote changes, and they have the human and scientific knowledge to move forward. With the constant and colossal changes in the marketplace, the technical skills taught at HEIs 'today' will no longer be of any utility 'tomorrow', being the time difference between 'today' and 'tomorrow' narrower each day.

With the aforementioned ideas in mind, we describe our experiences in the application of AL teaching frameworks at ISEP. In Section 2 we provide a brief summary of the implemented AL techniques. This is followed in Section 3 by the description of the application of the AL teaching environment in several Math courses. Then, in Section 4, we highlight the main challenges arisen from the COVID-19 pandemic in the . Finally, we discuss the lessons learned from the DrIVE-MATH journey at ISEP in Section 5.

2 AL techniques - brief summary

In this section, we describe in more detail the AL teaching techniques, namely Jigsaw, eduScrum, Think-Pair-Share, Buzz, case studies, problem-based-learning [37, 43, 44, 51, 48, 49, 50, 39, 35].

Jigsaw

Jigsaw is a cooperative technique in which the teacher facilitates students' learning. His role is not to teach but to ease students' learning process. Students learn and teach in groups, ie., among their peers. Biggs says that 'Most people learn 95% of what they explain to others' [19]. All students in the groups must learn and teach their specific content

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to others. The later increases responsibility and students' social skills, namely communication and teamwork. In the end, the teacher must check if students have adequately understood the contents of that class. The later may be done with some quiz questions in the end of the class, or any form of evaluation considered valid by the teacher. The implementation of Jigsaw, in a theoretical class in which 4 concepts must be apprehended by the students, is generically designed as follows. The teacher must prepare notes for each of the topics, and these notes are made available to all students. Then students are gathered in groups of 4. These are called the Home groups. Each student in these groups learns one of the 4 concepts individually. This task may take 10 minutes. Then, all students who have learned topic i , $i = 1; \dots; 4$, move to an Expert group for that specific topic i . There, they take 10 minutes to discuss between peers the key points of that topic and how they will instruct it to the other members of their Home groups, when they return. There, they have 10 minutes to teach their peers. In the end of this activity, the teacher verifies the degree of understanding of the 4 concepts by all students [5]. We apply Jigsaw in the theoretical classes [48, 43]

Figure 1: Jigsaw activity [4].

EduScrum

Scrum is a framework for project management in which teamwork, accountability and iterative progress, towards a well-known objective, are highlighted [10]. The main foundations of Scrum are transparency, inspection and adaptation. EduScrum is an adaptation of Scrum to education. Schools are using Scrum to boost students' learning, in an enjoyable team group way. Application of Scrum is associated with a higher quality of education, better grades and higher motivated students. The applicability of eduScrum is done by pre-defining events, the so-called time-boxed events, to generate a sense of regularity and predictability. Each event in Scrum is an opportunity to inspect and adapt something, which enables critical transparency. The core of

eduScrum is the Sprint. A Sprint is a logical set of learning material, designed to accomplish a certain learning goal. The time to execute a Sprint is pre-set, something up to two months, so student teams plan well and manage the complexity of the task. The timetable of the Sprint starts with the Sprint Planning Meeting, followed by the Team Formation. The Student Teams plan their actions independently during the Sprint. Stand-ups allow teams to discuss assignments and tasks within the Sprint, at the beginning of each class. The Sprint ends with a review and retrospective, students inspect their final work and enumerate possible ameliorations [60]. In our case-study, we implement eduScrum as follows. We (teacher owner) will propose a list of exercises (input tasks) in the practical classes (sprints). Students in class are asked to form groups of 4/5 members each (the team). After forming the groups, students will choose a Student Master, who is responsible for distributing the tasks to each member of the group. This procedure ends with a Sprint Review, where it is performed the sprint assessment. The later consists of 3 components:

1. assessment of performed tasks - usually calculating the weighted average of accepted tasks;
2. not well performed tasks are graded 0;
3. assessing students' individual contribution by analysing the team's Scrum board.

In the Sprint retrospective students discuss key points of the solved tasks and make a brief report of what went well; what went wrong; what should be improved in the next Sprint [51, 49].

Figure 2: Flowchart of the eduScrum methodology [10].

Think-Pair-Share (TPS)

TPS is a collaborative learning strategy where students work together to solve a problem or answer a question about an assigned reading. This strategy requires students to [2]

think individually about a topic or answer a question; and [19] share ideas with classmates. Discussing with a partner maximizes participation, focuses attention and engages students in comprehending the reading material. The solution to any problem involves brainstorming ideas (Think), discussing methods among peers (Pair), analyzing results and communicating them (Share)[12]. We apply TPS in the theoretical classes. The teacher starts with an explanation of the topic for each specific class and then proposes an activity related to those contents to the students. The students must solve the problem as a team and explain the proposed solution to the class.

Figure 3: Think-Pair-Shate activity [13].

Challenge and Project-Based-Learning (CBL, PBL)

In a PBL context students learn and develop soft skills while working for long periods of time, from one week up to a few months, in a real-world problem or challenge. They thoroughly do research and provide a public product or a presentation to a wider audience. PBL inspires critical thinking, creativity and develops good communication skills in the students. This empowers students in their academic and future professional lives, ensuring that they embrace fully the 4th industrial revolution era [9].

Challenge-Based-Learning (CBL) is an active-learning framework to solve real world problems. It is a hands-on experiential learning which involves all participants, namely students, teachers, families, community members, promoting collaborative and cooperative work. Students work on open problems suggested by themselves or by the teacher. They spot big ideas, ask significant questions, uncover Challenges, and gain an in-depth knowledge on multidisciplinary concepts. It is a framework developed by 'Apple Classrooms of Tomorrow—Today' with Apple and educators where the goal was to develop students for life-long learn-

ers [42]. The framework is divided in three on-going and not stagnant stages, namely Engage, Investigate and Act composed by a set of activities, see 4. The first stage is composed by 3 sub-stages: a) Big Idea; b) Essential Questions and c) Challenge. The wide concept that will be explored by the students and where they will gain a multidisciplinary knowledge is called Big Idea. Then they will formulate a set of essential questions to contextualize and pinpoint the important concepts within the big idea. From this set of questions, one essential question related to the big idea that students want to explore must come out. Finally, the Challenge will be a stimulant way of solving the detected problem derived from the essential question. The second stage is composed by 3 sub-stages: a) Guiding Questions; b) Guiding Activities; and c) Guiding Resources. Once they move forward the first stage, they must search for questions (hypotheses) that help them to implement, develop and validate the solution. Then they prioritize the guiding activities such as bibliographic research, simulations, calculations, expert interviews, surveys, customer discovery, business model, etc. The guiding resources will be all the material where they can get information to relate the guiding questions and the guiding activities, namely: websites, videos, databases, contact information for experts, and other types of contents. The third stage is denominated Act and composed by three sub-stages: a) Solution; b) Implementation; and c) Evaluation. After defining correctly every step and the basic foundations for developing the solution in the other stages, students must select the best solution to be prototype, experienced and refined, the most viable product (MVP). The implementation and evaluation will occur in real environment with audience. They must reflect, take measures and balance the impact on the challenge.

Figure 4: Challenge-Based-Learning [42].

Figure 5: Combined Challenge-Based-Learning and Scrum [45].

We have applied the Scrum framework combined with CBL, in order to develop a most viable product (MVP) using four different scientific areas: Mathematics, Management, Informatics, and Electrical Engineering [45]. CBL was the teaching methodology, and Scrum an iterative agile software development approach was applied to develop concepts of team-working, planning, collaborative and cooperative work. The combination of CBL and Scrum is presented in 5. The implementation of Scrum and CBL has been considered previously in the literature, in the scope of an iOS development course [56]. There is some debate concerning the definitions of PBL and CBL. Researchers agree on that challenge may be part of a new type of PBL experience, the Gold Standard PBL experience, and a project can be developed as a CBL. The idea underneath is that all learners are fully engaged, divide responsibilities and share ownership, and work for the well-being of the community [42].

3 Math courses

In this section we summarize the application of AL teaching frameworks in several Math courses.

3.1 Differential and Integral Calculus I

The course of Differential and Integral Calculus I is part of the 1st semester of the first year of the Bachelor Degree In Biomedical Engineering. This is a course that aims to provide the students with basic scientific knowledge and techniques in the areas of Differential and Integral Calculus. These will be used in advanced curricular units.

In this section, we detail the course's plan for each academic year, since 2017–2018, and how the teaching techniques were implemented.

Academic year of 2017–2018

The course's syllabus was composed of five chapters, namely Differential Calculus in **R**, Indefinite and Definite Integrals, Numerical Series and Functional Series. At the end of the course, students were expected to be able to:

- apply different methods and techniques of derivation and integration.
- apply methods and techniques of derivation and integration to solve large problems.
- identify and characterize the convergence of series.
- know how to interpret problems with accuracy and detail, how to formalise them using appropriate math language, simplify, interpret and present the results obtained in the light of a critical spirit.
- Apply the contents learned to solve the new problems in the field of engineering.

This course runs with two distinct types of classes, namely lectures and practical classes. In the lectures, the Jigsaw technique is implemented, with students learning in base and expert groups. Students actively engage in their learning process and have a better understanding of their learning. In the practical classes, students learn with a modified version of eduScrum. They work in groups to achieve a common goal, which is solving a set of problems identified by the teacher, for each class. Peer-review is implemented to improve the quality of their work (Peer Feedback pattern). The assessment of this curricular unit consisted in the grades of five sprints, one after each chapter, and of two individual written tests.

In the end of the semester, 48 students attending the course [43], replied to an online questionnaire on Moodle. Students gave feedback of their perceptions with respect to the effectiveness of AL techniques, JigSaw and eduScrum, when compared to the traditional teaching methods (TM). Moreover, they graded in a 5-point Likert scale, the self-development of soft Skills, linked to the different methodologies. The analyzed skills included self-motivation, responsibility, communication, teamwork, flexibility, critical thinking, leadership, negotiation of conflicts. Statistical analysis disclosed positive correlations between questions regarding Jigsaw and eduScrum, and negative correlations for the TM environment. These results were supported by chi-square tests. Jigsaw and eduScrum are recognized by the students as beneficial for the enhancement of soft skills, in accordance with the literature [6], [7]. Problem-solving and critical thinking are also exploited in Jigsaw environments [29]. Figures 6-7 show that the overall results from students' perceptions on the development of soft skills for traditional methods teaching frameworks are below those for eduScrum.

Figure 6: Students' perceptions on development of soft skills, with the eduScrum Methodology.

Figure 7: Students' perceptions on development of soft skills, with traditional methods.

Academic year of 2018–2019

The Calculus course in 2018–2019 was similar to the previous year. The only difference was in the assessment, to which was added another summative component, corresponding to exercises solved on the Moodle platform.

These students were given the same questionnaire as the students of the previous academic year [50]. A comparison statistical study was performed and interesting observations were made. There is a consistent increase in students' confidence, from one year to the other, for all soft skills, with the exception of *Responsibility*. Moreover, the Mann-Whitney test, shows significant differences for *Teamwork* and *Communication*. Chi-square tests agree with MW, though it is not conclusive for *Communication*. We remark that the proportion of students with very high positive perceptions ('Strongly agree') increased for the soft skills of *Teamwork*, *Flexibility*, *Leadership* and *Communication*. Moreover, all other skills kept very good ratings by the students. This indicates that despite the fact that most students were taught only by traditional methods in sec-

ondary education, they are open to other teaching styles in Higher Education.

Academic year of 2019–2020

In 2019–2020, the teacher responsible for the course decided to change the syllabus, to include a chapter on Sustainable mathematics, where students were given case-studies to apply differential and integral calculus. The other chapters, in particular the one of series was reduced. This change also induced a slight modification in the teaching methods. The theoretical classes were delivered according to the Think-Pair-Share Technique (TPS). In chapter 5, students were asked to present their solutions to the proposed case-studies, and the AL techniques included teamwork, peer-evaluation, flipped-classroom. Students actively engage in their learning process, working autonomously. They composed slides, they searched the internet for Math and other educational tools, to enrich the active participation of their peers in class. They used PollEv, Kahoot, Eclipse-Crossword, among others. Some groups prepared leaflets to distribute among their peers on Climate Change, and others, since some case-studies included these issues. Each group complemented their work with a poster and a written assignment. To do the poster, the students used a variety of tools, Microsoft Powerpoint, Microsoft Publisher, and some available online, namely Canvas, Piktochart. The written assignment had a series of tips to help structure and organize the contents.

The practical classes were taught following the eduScrum methodology, and consisted in solving problems/exercises associated with the contents of the lectures.

The summative assessment consisted in a group grade and an individual grade. The group grade added the points gathered from the eduScrum sprints and from the presentation of the case-studies in the lectures. The individual grade was obtained from the individual written test.

In the end of the semester, 44 students, attending the course, replied to a survey focused on students' perceptions on the AL methodologies and their own competences [35, 39]. A five-point rate Likert scale (Strongly disagree, Disagree, Slightly agree, Moderately agree, Strongly agree) was used for each question. Principal Component Analysis was applied to identify associations between questions (variables). The quality of the correlations between the variables was verified using the Kaiser-Meyer-Olkin (KMO) measure and the Bartlett's Test for Sphericity (BTS) [30]. To extract factors using PCA were adopted, as loading factors, the values greater or equal than 0.50. The analysis identified three distinct factors, which we characterized as cognitive, interpersonal, and personal skills,

with corresponding Cronbach's alpha coefficients of 0,775, 0,822 and 0,734. Moreover, a ranking score was computed for each set of skills. Were observed high values, which indicate that AL perceived as an efficient strategy by the students, for developing those skills. The highest scores were assigned to the questions related with Interpersonal skills, which are a strong indicator of a future professional career [62].

In another questionnaire, the students were asked to provide their feedback on questions regarding three specific areas, namely, 'Teaching methods', 'Knowledge acquisition', and 'Soft Skills' [18].

Figure 8: Students' perceptions with respect to teaching methods and assessment [18].

Figure 9: Students' perceptions with respect to knowledge acquisition [18].

Students were comfortable with the applied teaching methodologies and provided positive feedback. In fact, they pointed the case-studies' approach as contributor to the increase of their knowledge in Calculus. Most learners appraise that analytical and synthesis skills' development is benefited by this learning framework. With respect to assessment methods, students appraise like application

Figure 10: Students' perceptions with respect to the development of soft skills [18].

of AL techniques in other courses. Nonetheless, they feel these techniques require more effort from their own side.

3.2 Statistical Models

The course of Statistical Models (SM) is a mandatory curricular unit of the scientific area of Mathematics and is included in the course's plan of the Baccalaureate in Biomedical Engineering, in the 2nd year, 2nd semester.

Academic year of 2017/2018 and 2018/2019

The syllabus of the SM course includes topics of Probability Theory and Discrete and Continuous Distributions, the Central Limit Theorem, Confidence Intervals and Hypothesis Testing, and Linear Regression. It is planned to provide students with (i) a solid base of mathematics and (ii) a statistical knowledge to solve medium-complex problems of Biomedical Engineering. We underscore problems requiring data analysis and interpretation, forecasting, and decision making. Students should be able to solve the problems of Biomedical Engineering, according to the level of education that they belong to. The course syllabus was designed with the objective of providing the students with a fundamental knowledge of probabilities, namely definition, discrete and continuous probabilities most used in real world problems, Normal Distribution Additive Theorem. These will be the foundations on which the Sampling, the Parameter Estimation and the Hypotheses Testing Chapters are based, culminating in the Linear Regression. With these programmed contents, students have acquired the know-how to address the problems they have to solve, at their level of education. Moreover, the research work they have to execute during the semester, on application of statistics to solve real world problems, will allow the development of scientific research and SOFT SKILLS, namely, teamwork,

peer-communication and brainstorming, emotional intelligence and conflict management. This will promote progress in students' work and social lives, now and in their future.

The SM course is delivered by lectures and practical classes. The teaching environment is based on AL strategies [63, 47]. In this course, the teacher included Think-Pair-Share (TPS), Buzz, and Q&A sessions in her lectures [3, 1]. In the practical classes was implemented a modified eduScrum method. Students work together to solve problems associated with the contents of the lectures. The students learn in teams.

Academic year of 2019/2020

Students attending this course were faced to a fully online regime on the second semester, due to the COVID-19 pandemic outbreak after just one week of face-to-face classes.

The Portuguese government imposed a full confinement, after the initial exponential rise of infectious numbers. As the pandemic evolved positively, with fewer number of infectious and deaths, the countries started to ease the lockdown restrictions. Nevertheless, the second semester ended without any change in the teaching framework.

The SM syllabus was changed to include a final chapter, devoted to real world case applications (CS) of statistical techniques. Other chapters, namely Chapters 1 and 2 of the previous syllabus were summarized, due to students' prior knowledge.

In the COVID-19 setup, the edu-teamwork environment encompassed breakout rooms per each group. Each online class was started by the teacher in one single virtual room for all students. After delivering the worksheets for that class, the teacher sent groups of students for breakout rooms. Ten minutes before the end of the class, all, students and teacher, reunited on the primary online room. The teacher was available to discuss the materials with the students during classes and virtual office hours.

The teaching methodology is similar to the one of previous years. The only perturbation refers to last chapter of the syllabus. The lectures and practical classes of the course are all devoted to the development of solutions to the case-studies (CS). In the end of the semester, the students have to publicly present their solutions to the CS. Adding to this, each team has to write a scientific report, and do a poster. The underline AL methods for these classes were peer-evaluation, flipped-classroom, and brainstorming.

In the end of the semester these students were asked to reply to a survey, consisting of one open-question and several ended-questions, to be replied using the 5-point Likert scale. Were addressed three main topics: teamwork,

assessment, and online classes environment. Figure 11 depicts students' opinions on teamwork. Are observed high positive results, revealing students' likeliness to work in a team and also self-confidence in owns abilities. More information can be found at [46].

Figure 11: SM students' perceptions on teamwork on the academic year of 2019/2020 [46].

3.3 Computational Mathematics

Academic year of 2017/2018

The unit of Computational Mathematics (MATCP) is part of the 1st year - 2nd semester of LEI and is a basic course. The classes of this unit will be oriented towards the development of students' reasoning and abstraction skills. It is intended that students acquire and apply fundamental concepts of statistical methods, especially in terms of interpretation and statistical reasoning of decisions.

- Identify, interpret and apply appropriate probabilistic models to solve applied statistical problems.
- Identify and apply some statistical models associated with the average and the proportion of random samples.
- Justify decisions based on parametric statistical inference.
- Make estimates and decide
- Apply statistical methods to simple and specific problems in their area of Computer Engineering

The teaching method presumes a strong interaction between lectures, practical classes and lab classes. The students must participate in an active and regular way in each. The practical classes are focused on problem solving tech-

niques, The practical classes are focused on problem solving techniques. The eduScrum (simplified) methodology is used to support effective teamwork and to foster student involvement. The Peer Feedback, Groups Work and Embrace Correction pedagogical patterns are dominant.

The classes of this unit will be oriented towards the development of students' reasoning and abstraction skills. It is intended that students acquire and apply fundamental concepts of numerical methods and statistical methods, especially at the level of interpretation and statistical reasoning of decisions.

- Identify, interpret and apply probabilistic models to solve Statistics problems.
- Identify and apply some statistical models associated with the average and proportion of random samples.
- Justify decisions based on parametric statistical inference.
- Calculate estimates and make decisions.
- Know how to analyze the numerical result of a problem.
- Solve numerically algebraic and transcendent equations.
- Determine the function associated with a set of tabulated points.
- Apply numerical and statistical methods to specific problems in the area of Computer Engineering.

The teaching and learning methodologies aim the integrated development of the students referred to in the syllabus contents and the achievement of the established objectives and competences. The diversity of proposed methodologies aims to promote different approaches and learning in a perspective of complexity, seeking to highlight different levels of analysis, promoting the integration of knowledge. The proposed methods and strategies aim to develop students' knowledge, understanding and skills at the application level, enhancing the "soft skills of the 21st Century Engineers". Theoretical classes based on the expository, interrogative method and active methodologies, life-long learners. The objective of the theoretical-practical classes is to guide the student in the practical application of the concepts and subjects taught in theoretical classes. Practical-laboratory classes will be based on the active method - Groups work; Challenge understanding; Different exercises levels.

Course's Framework

In second semester of the academic year of 2017/2018, it was implemented the active learning methodologies in the course of Computational Mathematics of the Bachelor Infor-

matics Engineering Degree at ISEP. This study targeted 384 students, separated in 5 theoretical lessons (T) with about 80 students each, 11 practical classes (TP) and 21 Practical Labs (PL) of 15 students each. 'Typical' (traditional) T classes sizes can run from 80 to 100 students, with varying levels of individuals' needs and support, whereas TP classes consist at most of 30 students and PL runs from 15 to 22 students. The figure 12, shows the distributions of different pedagogical methods (JigSaw, eduScrum and traditional way of teaching) applied to each class. The course

Figure 12: Distribution of each pedagogical method according to class type in Matcp [39].

has a team composed by 9 professors with more than 20 years of experience at ISEP. Table 13 was designed to inform each teacher of the type of lectures, methodology applied, tasks and evaluation for each class.

Teacher	Lectures	Methodology	Task	Evaluation
X	T/Practical	Traditional	Blackboard exercises	Eduscrum/Excel sheet
	Practical Labs	Jigsaw	Blackboard exercises	Moodle feedback/Excel sheet
Y	Theoretical	Traditional	Teaching	Eduscrum/Excel sheet
	Practical Labs	Eduscrum	Blackboard exercises	Eduscrum/Excel sheet
Z	T/Practical	Eduscrum	Blackboard exercises	Eduscrum/Excel sheet
	Practical Labs	Eduscrum	Blackboard exercises	Eduscrum/Excel sheet
W	Theoretical	Jigsaw	Teaching	Eduscrum/Excel sheet
	Practical Labs	Traditional	Blackboard exercises	Eduscrum/Excel sheet
K	T/Practical	Traditional	Blackboard exercises	Eduscrum/Excel sheet
	Practical Labs	Eduscrum	Blackboard exercises	Eduscrum/Excel sheet
Q	Theoretical	Traditional	Teaching	Eduscrum/Excel sheet
	Practical Labs	Eduscrum	Blackboard exercises	Eduscrum/Excel sheet
P	T/Practical	Traditional	Blackboard exercises	Eduscrum/Excel sheet
	Practical Labs	Traditional	Blackboard exercises	Eduscrum/Excel sheet
M	T/Practical	Traditional	Blackboard exercises	Eduscrum/Excel sheet
	Practical Labs	Eduscrum	Blackboard exercises	Eduscrum/Excel sheet
A	T/Practical	Traditional	Blackboard exercises	Eduscrum/Excel sheet
	Practical Labs	Eduscrum	Blackboard exercises	Eduscrum/Excel sheet

Figure 13: Distribution of each pedagogical method according to class type in Matcp [39].

Theoretical Lessons

In the theoretical classes, we implemented a hybrid teaching framework: some classes are taught using the tradi-

tional approach (TM), and some are taught applying the Jigsaw method of AL methodology. The Jigsaw framework is based on a self-teaching strategy and was applied in 3 Theoretical classes. The students of the other 3 Theoretical classes were taught by the traditional method (TM), with the usual talk and chalk approach. Implementing Jigsaw in a class is achieved through the following procedure. The teacher must prepare notes for each of the topics, and these notes are made available to all students a priori. In class, the teacher starts by giving information about the global topic and the 4 subtopics which are intended to be learned. Students are then gathered in groups of 4, the so called Home groups. Each student studies one particular subtopic individually. This task may take 10 minutes. Then, all students who have learned subtopic i , $i=1,2,\dots,4$, move to an Expert group, for that specific subtopic i . There, they take 10 minutes to discuss between peers the key points of that subtopic and how they will teach it to the other members of their Home groups, when they return. After returning, they have 10 minutes to teach their peers. In the end of this activity, the teacher verifies the degree of understanding of the 4 subtopics by all students.

Practical Lessons

To implement the active learning approach with different methods, we applied in the practical classes of the Computational Mathematics course, the eduScrum methodology, as a part of an AL process. The 11 practical lessons were also divided in two categories, in 5 of them the eduScrum method was implemented and in the other 6 was used the traditional method. The course consists of 12 weeks. Each practical class of 37 students was split in 6 or 7 groups, of 5 or 6 students each. Every two weeks, students had Sprints, where they have to do a set of proposed exercises and are evaluated accordingly (please see 14). In this scenario students are exposed to some discussion between their peers and with the teacher, which is an essential part of a mathematical classroom.

Practical Lab Lessons

Practical Lab Lessons (PL) were also divided in two models, 13 using the traditional method and 6 of them the eduScrum method. Each PL of from 15 to 22 students were split in 4 to 5 groups, of 4 students each. Every two weeks, students had Sprints, where they had to do a set of proposed exercises and were evaluated accordingly (please see table1). PL where prevails the traditional method, the exercises were done in the blackboard by the teachers and the evaluation of the different topics of the subject were done every two

weeks (called sprints). These sprints were done by each student on the Moodle platform in the form of quizzes. The PL classes that prevails the eduScrum method, the role of the teacher was coaching the students. The teacher ask the right questions, to promote greater self-awareness and foster more informed decision making, so that the students can learn something. In this type of lessons is not the role of teachers that will solve problems, but rather, promote discussions, observations, pre-observations to collaboratively promotes the students learning. This will help students to think critically and be a life long learner. Every two weeks, Sprints, they had to present to the teacher the tasks solved and teachers put the evaluation of each student in an excel sheet 14.

Week 2										Week 3					Week 4					Week 5				
24/02/2018		24/02/2018		24/02/2018		24/02/2018		24/02/2018		24/02/2018		24/02/2018		24/02/2018		24/02/2018		24/02/2018		24/02/2018				
PL		PL		PL		PL		PL		PL		PL		PL		PL		PL		PL				
Prepared		Prepared		Prepared		Prepared		Prepared		Prepared		Prepared		Prepared		Prepared		Prepared		Prepared				
Total of Ex.		Total of Ex.		Total of Ex.		Total of Ex.		Total of Ex.		Total of Ex.		Total of Ex.		Total of Ex.		Total of Ex.		Total of Ex.		Total of Ex.				
Mark		Mark		Mark		Mark		Mark		Mark		Mark		Mark		Mark		Mark		Mark				
Prepared		 		Pre														

Figure 14: Excel Sheet to evaluate students' sprints in Matcp [39].

Students' Perceptions

Students' perceptions of the implementation of AL techniques along the course were evaluated from the responses to posed questionnaires. In Matcp 102 students replied in the second semester of the academic year 2017/18.

The questionnaires of Matcp suffered an upgrade in the questions posed to the students, since this course contains different class typologies and requires Excel programming tasks. Moreover, the authors with the experience from the 1st semester notice that the questionnaire should have different questions to gauge and assess more precisely the implementation of new methodologies applied in each course. The students had good perceptions on these methodologies 15, evidenced by the following questions "Solve problems in a group during class"; "Discuss concepts with classmates during class"; "Teamwork"; "The discussion of the topics between peers" and "I consider myself resilient when facing difficulties in some exercises in laboratory classes". Students enjoy working in groups and the increase in the responsibility of their learning process.

Academic year of 2018/2019

In the academic year of 2018/2019, the previous framework was implemented. However, in lab-classes it was occurred a slight modification regarding the assessment of the sub-

Figure 15: Matcp Students' perceptions. [39].

ject related to numerical methods. The students were faced with a challenge and they had to make a group work with presentation. This work is mandatory for all students enrolled in this curricular unit. The Statistical component will be evaluated through a test.

Academic year of 2019/2020

The Matcp syllabus was revised, by removing the numerical methods topics, thus turning it into a statistical Methods course composed by three main topics. The first one, is "Probability theory" followed by "Descriptive statistics" and the last topic is "Statistical parametric inference". These contents were delivered by lectures, practical and laboratory classes. Every week the students had to solve a set of exercises and a practical work exclusively done in Excel. The lectures were delivered by online synchronous classes through Zoom. The practical classes followed the same online format where students developed individual work solving exercises supervised by the teacher. In the laboratory classes, the students solved a practical Excel work. The students worked in teams with 4 or 5 elements. At the end of each lab class, they submitted two files on Moodle, one with the resolution and other with a self-evaluation of each member of the group. According to the Excel work and self-evaluation the students were graded by the teacher.

3.4 Linear Algebra and Analytical Geometry

This subsection details the AL methods implemented in the Linear Algebra and Analytical Geometry (ALGAN) course, of the Baccalaureate on Informatics Engineering at ISEP, in the academic year of 2017/2018.

The courses' syllabus is split into five chapters, being the first three devoted to Linear Algebra and the last two to Analytical Geometry. Linear Algebra is one of the most important areas in Mathematics, having at least as great an impact as Calculus. The first chapter includes real matrices. Students learn the basic operations on matrices, namely addition, scaling, and multiplication, distinguish types of matrices, transpose of a matrix, inverse matrix, rank of a matrix. The second chapter comprises determinants. Students are given the definition of the determinant of a matrix, its properties and learn distinct methods for its calculation. The third chapter comprises the study of systems of linear equations. The topics involve the definition of a Cramer system, homogeneous systems of linear equations, the fundamental system of solutions and the set of solutions. The fourth chapter includes vector spaces, linear dependence and linear independence of vectors, dimension of vector spaces, bases, dimension of a basis, representation of a vector in a base, vector subspace, general and parametric equations of subspace. The fifth chapter includes definition and properties of a linear transformation, the kernel and image of a linear transformation, and the matrix of a linear transformation in two bases.

The course is taught in 12 weeks, with a total of 12 hours of theoretical classes and 48 hours of practical classes, summing 60 contact hours.

Course's Framework

In the ALGAN course, both theoretical and practical lessons were explicitly divided in traditional and AL methods, using a similar structure as of Figure 12 [37]. We had three theoretical lessons running with the Jigsaw Method (JS), and two theoretical lessons with the traditional method. Five of the ten practical classes run with the eduScrum method (EDS), and the other five with the traditional method (TM).

Theoretical Lectures

In the traditional lectures the students absorbed information, with a monologue form of communication. The teacher was the central speaker, possessing, and broadcast expert knowledge to a 'less expert' audience. In the theoretical classes taught using JS, the students had a more active role in their own learning process. The existence of these two types of classes served as a benchmark for comparison between groups taught by AL or by TM methods.

Practical Lectures

In traditional practical lessons, the teacher solved and explained a series of exercises on the white board and students copied the solutions to their notebooks. A set of exercises was proposed, from a worksheet provided by the teacher, see Fig. 17. Every 2 weeks, the students had an individual written mini-test (Fig. 16), on the Moodle platform. This provided continuous feedback to these students.

Let $A = \begin{bmatrix} 0 & -1 & 2 \\ 1 & -1 & 2 \\ 3 & 1 & 0 \end{bmatrix}$, $B = \begin{bmatrix} 2 & 5 & 7 \\ 1 & 5 & 9 \end{bmatrix}$ and $C = \begin{bmatrix} 0 & -1 & 2 \\ 2 & 6 & 10 \end{bmatrix}$

Find the logical value for:
 i. $(B - C)^T C$ is a matrix with dimension 3×3
 ii. BAC^T is a rectangular matrix

Selecione uma opção de resposta:

☐ i. False , ii. True
☐ i. True , ii. False
☐ i. True , ii. True
☐ i. False , ii. False

Let $A = \begin{bmatrix} -4 & -3 & -6 \\ 2 & 1 & 1 \\ -1 & -1 & -1 \end{bmatrix}$, $B = \begin{bmatrix} 3 & -1 & 1 \end{bmatrix}$, $C = \begin{bmatrix} 1 & -1 & 1 \\ -1 & 1 & 0 \\ 2 & 1 & 2 \end{bmatrix}$

The matrix operations are possible in :

Selecione uma opção de resposta:

☐ $(A^T - C^T) B^T$
☐ $AB^T C$
☐ $C B^T A$
☐ $B^T (A^T - C^T)$

The matrix $A = \begin{bmatrix} 4 & -3 & -6 \\ 1 & 0 & -1 \\ -1 & -1 & -1 \end{bmatrix}$ is equivalent to

Selecione uma opção de resposta:

☐ $\begin{bmatrix} 4 & -3 & -6 \\ 1 & 0 & -1 \\ 0 & 0 & -2 \end{bmatrix}$
☐ $\begin{bmatrix} 1 & 0 & -1 \\ -3 & 0 & -2 \\ 0 & -1 & -2 \end{bmatrix}$
☐ $\begin{bmatrix} 1 & 0 & -1 \\ 0 & -1 & -2 \\ 0 & -1 & -1 \end{bmatrix}$

Figure 16: Mini-test for traditional practical lessons.

Each practical lesson under the eduScrum methodology, applied the ceremonies, tools and roles of the Scrum framework. Every lesson started with a stand-up to discuss and reinforce the team spirit, keeping everyone aware of the team's work and progress. The Scrum master was responsible to distribute the exercises among each peer. He planned and determined the activities of his group and kept track of the progress. The role of the teacher was to determine the assignments, coach and give advice. In figures 17 and 18 are shown examples of worksheets, with respect to the topics of elementary row operations and rank of a matrix. From these worksheets were selected 9 exercises to

complete in 2 practical classes. There were retrospectives to help the students to continuously improve their Math techniques and knowledge. After finishing the exercises, the professor assessed students' answers to the exercises, using a scale from 0 to 1 for each exercise. A zero grade meant the exercise was incorrect, and a 1 was given when the solution was correct.

Informatics Engineering BSC
 Linear Algebra and Analytical Geometry
 1st Semester 17-18
 TP Matrices-Elementary Row Operations

1. Let $A = \begin{bmatrix} 0 & 0 & 3 \\ -1 & 1 & 0 \\ 1 & 0 & 2 \end{bmatrix}$ and $B = \begin{bmatrix} 1 & 0 & 2 \\ 0 & 1 & 2 \\ 0 & 0 & 1 \end{bmatrix}$.
 Determine if A is equivalent to B .
 Hence, indicate the elementary operations.

2. Let $A = \begin{bmatrix} -1 & 0 & 0 & 3 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & -2 & 4 \end{bmatrix}$ and $B = \begin{bmatrix} 1 & 0 & 0 & -3 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 1 & -2 \end{bmatrix}$.
 Determine if A is equivalent to B .
 Hence, indicate the elementary operations.

3. Let $C = \begin{bmatrix} 0 & 1 & 1 & 2 \\ 2 & 0 & 3 & 5 \\ 1 & 1 & 1 & 3 \end{bmatrix}$ and $D = \begin{bmatrix} 1 & 0 & 1 & 2 \\ 0 & 2 & 3 & 5 \\ 1 & 1 & 1 & 3 \end{bmatrix}$.
 Determine if C is equivalent to D .
 Hence, indicate the elementary operations.

4. Let $E = \begin{bmatrix} 1 & 2 & -1 & 5 \\ 3 & 1 & -2 & 9 \\ -1 & 4 & 2 & 0 \end{bmatrix}$ and $F = \begin{bmatrix} 1 & 2 & -1 & 5 \\ 0 & 1 & 2 & -1 \\ 0 & 0 & 1 & -1 \end{bmatrix}$.
 Determine if E is equivalent to F .
 Hence, indicate the elementary operations.

5. Let $G = \begin{bmatrix} 1 & -1 & -1 & 2 & 0 \\ 2 & 1 & -1 & 2 & 8 \\ 1 & -3 & 2 & 7 & 2 \end{bmatrix}$ and $H = \begin{bmatrix} 1 & -1 & -1 & 2 & 0 \\ 0 & 1 & 4 & 3 & 10 \\ 1 & -3 & 2 & 7 & 2 \end{bmatrix}$.
 Determine if G is equivalent to H .
 Hence, indicate the elementary operations.

1 Linear Algebra and Analytical Geometry

Figure 17: Worksheet for the eduScrum classes: Elementary Row Operations.

In this type of TP classes, we encouraged teamwork, by promoting students' responsibility for each others learning. Students worked together in a given task, where each one was responsible for a specific sub-task, adhering to deadlines. The exercises were designed to have distinct degrees of (knowledge) complexity. Students had time to analyze, listen, think and provide distinct solutions. This built and maintained students' confidence. The idea of seeing before hearing was underneath this framework, providing students with the opportunity to finish a hands-on challenge. Exercises were available in advance, on the Moodle platform, to enable prior access to students to stimulate them to try to find a solution, before listening to the teacher. Students become artisans of their own knowledge.

 Informatics Engineering BSC
 Linear Algebra and Analytical Geometry
 1st Semester 17-18
 TP Matrices-Rank of a matrix

1. Determine the rank of the following matrices.

(a) $A = \begin{bmatrix} 0 & 16 & 8 & 4 \\ 2 & 4 & 8 & 16 \\ 16 & 8 & 4 & 2 \\ 4 & 8 & 16 & 2 \end{bmatrix}$ (b) $B = \begin{bmatrix} 4 & -6 & 0 \\ -6 & 0 & 1 \\ 0 & 9 & -1 \\ 0 & 1 & 4 \end{bmatrix}$

(c) $C = \begin{bmatrix} 1 & 5 & 1 \\ 2 & 1 & 1 \\ 3 & 6 & 2 \end{bmatrix}$ (d) $D = \begin{bmatrix} 2 & 6 & 2 & 6 \\ -2 & -8 & 3 & -4 \\ 3 & 3 & 8 & 16 \end{bmatrix}$

(e) $E = \begin{bmatrix} 1 & 2 & 0 & 5 & -2 & 1 \\ 1 & 2 & 0 & 5 & -2 & 1 \\ 1 & 2 & 0 & 5 & -2 & 1 \\ 1 & 2 & 0 & 5 & -2 & 1 \end{bmatrix}$ (f) $F = \begin{bmatrix} 1 & 0 & 2 \\ 2 & 1 & 1 \\ 1 & 1 & 0 \end{bmatrix}$

(g) $G = \begin{bmatrix} 3 & 2 & 1 & 4 \\ 2 & 2 & 1 & 2 \\ -5 & -4 & -2 & -6 \end{bmatrix}$

2. Judge whether the following vectors are linearly independent.

$\begin{bmatrix} 3 & 0 & 1 & 2 \\ 6 & 1 & 0 & 0 \\ 12 & 1 & 2 & 4 \\ 6 & 0 & 2 & 4 \\ 9 & 0 & 1 & 2 \end{bmatrix}$

3. Determine the rank of the matrices, without any calculations.

(a) $X = \begin{bmatrix} 2 & 2 & 2 \\ 4 & 4 & 4 \\ 6 & 6 & 6 \end{bmatrix}$ (b) $Y = \begin{bmatrix} 3 & 0 & 5 \\ 1 & 0 & -1 \\ 8 & 0 & 6 \end{bmatrix}$

(c) $Z = \begin{bmatrix} 3 & 3 & 3 \\ 3 & 4 & 3 \\ 3 & 4 & 3 \end{bmatrix}$ (d) I_6

4. Find the rank of matrix A, as a function of parameter $m \in \mathbb{R}$.

1
Linear Algebra and Analytical Geometry

Figure 18: Worksheet for the eduScrum classes: Rank of a matrix.

Students' Perceptions

Several articles have been published [37, 51, 48, 43, 44, 49], concerning the analysis of students' perceptions on the application of the AL methodologies, namely Jigsaw and eduScrum, in the ALGAN Course.

Throughout this section we will summarize the main conclusions taken from the statistical analyses of data collected from surveys addressed to students. The surveys were done on the Moodle platform (figures 23, 24, 25).

In [43], we evaluated students' perceptions to the benefits associated with the JigSaw and eduScrum techniques, as opposed to the traditional methods. The results revealed that JigSaw increased communication skills and teamwork. The students also felt more responsible for their own and peers' learning processes. Other pertinent gains were the development of critical thinking and problem-solving, also emphasized for the eduScrum teaching framework.

In [44], 210 students replied anonymously to an online questionnaire on Moodle. Of these 104 students were exposed to AL methodology (Jigsaw and eduScrum); and 106 students were exposed to the traditional methodology. All students were asked to give their opinion on the development of the three skills, namely Leadership, Ability to work under pressure and time management, and Negotiation and conflict. The analysis of the results suggest that

the AL framework helps developing a skilled leader, one who inspires others to achieve own's and team's goals. An effective team leadership also requires an excellent time management, effective negotiation and conflict resolution. Good negotiation in a team forms the basis of all successful projects. Moreover, the group composition is also relevant, and in our classes, the teams were composed of students with complementary skills and attitudes. In a negotiation and conflict management, students gain deeper knowledge of themselves and of their peers.

All of these skills will strengthen students' future professional resilience. As Stephanie Lukins said 'Today's students are tomorrows workforce' [11].

4 COVID-19 disruption in Education

The COVID-19 pandemic has significantly disrupt our World. The SARS-CoV-2 virus shut every system and confined millions of people. Its consequences are seen socially, economically, in work environments, Education. This pandemic accentuated the existing hole between rich and poor, and disregarded nationality, level of education, income and/or gender. Adaptation to new life styles, working conditions, etc, were felt severely by everyone, but access to technology and having well payed jobs helped. The employees with low income and low education were the ones who suffered the most, being, the majority of them, sent to unemployment. The trust in public services, namely Health Services, Political Systems, was damaged and prompt responses were demanded by the entire society.

Education was also deranged, with Universities being forced to brusquely modify all courses to an online format, disregarding scientific areas or level of education. Everyone in the Education theater had to adapt. Teachers and students quickly and unprepared rushed to online communication platforms, such as Teams, Zooms. This teaching practice is known as emergency remote teaching (ERT), in dissimilarity with the planned and designed online learning framework [46]. The reverberations of this teaching apparatus are felt by teachers and students, and will echo during months, perhaps years. Furthermore, students from disadvantaged backgrounds are severely affected, due to small or null access to electronic devices and wireless networks, which hampers the frequency of their online classes [26].

At ISEP, the second semester of the academic year of 2019–2020, started with one week of *in-situ* classes, one week of teaching mode adaptation, and then a fully online regimen was established, due to the mitigation and suppression measures approved by the Portuguese Government. At

the end of the semester, us, the teachers were scientifically curious to know how this ERT regimen had affected students' satisfaction with the learning process. The analysis of a survey on students' perceptions on engagement, communication, time management, acquired knowledge, type of online courses (asynchronous vs synchronous), teamwork, and preferred teaching method, provided evidence of dissatisfaction. The majority of students chose *in-situ* classes and the remaining said they would appreciate a mixed framework, commonly known by b-learning. The main gains of this fully online regime, pointed by students are the flexible study hours, the travel time sparing to and out of university. The leading drawbacks were the lack of motivation, lack of focus, increased learning time consumption, struggling in knowledge acquisition and absence of the *in-situ* office hours to discuss the material being presented in class 20-21. Students miss the closed contact with the teachers. Additionally, they are eager to social contact with their peers [36, 17]. In contradiction with other literature [22], our students did not meet many network problems and study place was acceptable. Figure 19 compiles the main keywords gathered from the responses to open questions posed to the students in the questionnaires.

Figure 19: Identified keywords in the open-questions' responses from the course of Matcp [17].

Summing up, COVID-19 pandemic has brought to light several inadequacies and inequalities in our educational systems. Teachers, stakeholders, families, and students had to contribute to an educational supportive environment, to enhance focus on learning, and reduce *sine qua non* resources and needs.

Figure 20: Online students' perceptions on SM course [36].

Figure 21: Online Students' perceptions on Matcp course [36].

5 Lessons learned from this challenging experience

At the end of this project, we are now in a better position to evaluate the *bigger picture*, with respect to the application of AL techniques in Math courses taught at ISEP, in the scope of the DrIVE-MATH project.

Higher Education (HE) is known for being the incubator of former, current and of the future generation of entrepreneurs and leaders. It shapes agendas in public and private sectors, and has a strong effect on national and international economies. The reverberations of HE Institutions' impacts may provide a valuable instrument to achieve the change the World requires from us. This prompts strong action in these unforeseeable times of the COVID-19 pandemic, which severely impacted our entire lives, and severely disrupted our Health, Economical, and Educational systems. Troubled times demand strong action, and call for *Think and not sink*, or to *think as if there was no box*. At ISEP, we are

strongly committed to help shaping the future of our World, of our students. They demand and deserve restructured and updated courses, and this encompasses, unquestionably, the 4th sustainable development goal (SDG). It ensures *inclusive and equitable quality education and promotes lifelong learning opportunities for all* (SDG). Since school closures sent home more than 90% of all students worldwide and also in Portugal, the way Math courses, described in previous sections, were designed provided a perfectly adaptable teaching environment. The teachers responsible for these courses knew they had what was required to continue to provide a teaching of excellence. They used the available technologies and adjusted the AL techniques, initially thought for the courses, as well as some materials. Assessment was done through individual and group works. The breakout rooms were an indispensable tool of Zoom to achieve this. Similar tools are available in Microsoft Teams.

The implementation of AL techniques was demanding for the teachers, in a first approach. The teacher had to prepare the reading materials, adapting previous and developing new ones. Several questions have arisen, with respect to what contents do students need to learn, how should the tasks be designed so that the students effectively learn the topics, how can the teacher create positive classroom conditions in which students feel free to be intellectual adventurers, how can the teacher promote the development of skills while teaching the syllabus, among others. Additionally, there were colleagues who weren't familiar with AL teaching frameworks and to convince them to start implement AL was not an easy task. Though, AL benefits are recognised and a considerable literature is published on the topic [47], without proper involvement of relevant stakeholders, and collaboration among teachers, students, and even administrative staff, the task may fail, or, at least, be not as successful as one would expect. Another important issue on AL's implementation is technology. In our case, though technology was at hand within classrooms, these were very few and, most of the times, classical classrooms had to be adapted for each AL class. It adds to this that technology is extremely expensive and has a roughly five year old shelf life. This is where the involvement of stakeholders is vital to ensure ongoing support, and to the introduction of such spaces to be truly successful. Nevertheless, with suitable furniture, namely huddle or whiteboards, flexible chairs and tables, and equipment, AL classrooms may be a reality for more students and for ours too.

Our main lesson, if we are allowed to call it *lesson*, is that we are now even more confident that our students prefer AL to the traditional way of teaching. They feel more comfortable, they enjoy more active classes, they like to work in teams. With respect to the hard/technical skills/acquisition of Math knowledge, we observed that students with a lower grade performance showed more in-

Figure 22: Active-learning techniques (adapted from [14]).

terest in class and managed to increase the grade. This does not mean that retention rate was 0, this means that most students were successful. As it is known, some students attending Higher Education bring considerable Math deficiencies, from previous educational levels. This requires individual support from the teachers and a considerable amount of directed work from the students.

The students perceive that these teaching frameworks help them develop the essential skills of the 21st century. These skills must be like a second skin to students, and will effectively promote their perseverance in the lightning-pace of the Information Age's modern markets. Figure 22 shows the plethora of AL techniques made available to every teacher who accepts the challenge of AL and decides to start this amazing journey to the supreme success of our students. It is up to each teacher to select the AL tool which he/she would consider more appropriate for teaching his/her course. Main *advice* is to start with the easiest one, and step by step climb the ladder.

Welcome aboard!

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Appendix

5.1 Teaching plan

In this section, we describe in more detail the application of AL teaching techniques, namely Jigsaw, eduScrum, Think-Pair-Share, for one topic of Computational Mathematics.

Jigsaw Lesson Plan

Math course: Computational Mathematics

Subject: Discrete distributions

Summary: In this lecture we focus on the following concepts:

- Definition of a discrete random variable.
- Definition of a discrete distribution.
- Bernoulli distribution and Binomial distribution.
- Poisson distribution.

Length of Lesson: 50 minutes Outcome(s): The student will be able to:

- Identify and apply a general discrete distribution.
- Identify and apply the Bernoulli, Binomial and Poisson distributions.

Prerequisite:

Concepts:

- To apply the concept of probability.
- To apply probability laws.
- To apply Total Probability and Bayes' theorem.

Behaviors:

- To work in a team context.
- To communicate with their peers.
- To point written and verbal notes.

Materials:

- Sílvia Marques A. Gama, António Carvalho Pedrosa, *Introdução Computacional- Probabilidade e Estatística*, 2016, 3ª edição, Porto Editora
- Theoretical Slides <https://moodle.isep.ipp.pt>

Teaching mode: Jigsaw

Procedures:

List each procedure according to the stages of Jigsaw.

Preparation:

Pre-group the students in both expert and home groups.

Students are required to read the materials previously made available on Moodle, concerning the topics below.

- Definition of a discrete random variable.
- Definition of a discrete distribution.
- Bernoulli distribution and Binomial distribution.
- Poisson distribution

Expert Group:

Students who read the same topic will get into a group and further deepen their knowledge on the topic, by discussing relevant questions and reading more literature on the topic.

Home Group:

- The students move into groups with one person from each expert group.
- They explain their analysis of the studied topics and ask questions of the other group members.

Teacher:

- Do not interfere with the discussions.
- Walk around the room listening to what each group has to say.

Debriefing:

The class comes together to discuss/compare and contrast the similarities and differences between their comprehension on the different topics. This discussion will prevent them from leaving with unanswered questions and any uneasiness they may have felt.

Assessment Criteria:

After the debriefing, the teacher gets a formative general evaluation from all students in the classroom. The summative evaluation is done in the practical classes.

Eduscrum lesson plan

Math course: Computational Mathematics

Subject: Discrete distributions

Summary: In this lecture, the students solve several exercises concerning:

- General discrete distribution.
- Bernoulli distribution and Binomial distribution.
- Poisson distribution.

Length of Lesson: 100 minutes

Outcome(s):

The students will be able to:

- build a probability distribution table related to one general discrete distribution;
- build a probability distribution table related to one general discrete distribution;
- calculate the probability related to a random discrete variable which follows a general discrete distribution;
- calculate the probability related to a random discrete variable which follows a Bernoulli distribution;
- calculate the probability related to a random discrete variable which follows a Binomial distribution;
- calculate the probability related to a random discrete variable which follows a Poisson distribution.

Prerequisite:

Concepts:

- To apply the concept of probability.
- To apply probability laws.
- To apply Total Probability and Bayes theorem.

Behaviors:

- To work in a team context.
- To communicate with their peers.
- To point written and verbal notes.

Materials:

- Sílvia Marques A. Gama, António Carvalho Pedrosa, *Introdução Computacional- Probabilidade e Estatística*, 2016, 3ª edição, Porto Editora
- Theoretical Slides <https://moodle.isep.ipp.pt>

Model of Teaching: eduScrum

Procedures

List each procedure according to stages of eduScrum.

Preparation:

The teacher, as product owner, proposes a list of exercises (input tasks). Students are asked to form groups of 4/5 members each (the team). After forming the groups, students will choose a Student Master, who is responsible for distributing the tasks to each member of the group. The Student Master is expected to lead the team to the desired outcome. This means, he should provide an environment so that the correct solution of the exercises is found. In this way, he should be able to cope with distractions, disruptions, and obstacles that may appear, so the team reaches the goal. Students are required to read the materials previously made available on Moodle, concerning the topics of the class.

Teacher:

Do not interfere with the discussions. Walk around the room watching to what each group is doing.

Assessment Criteria (Sprint Review):

The sprint assessment consists of the following 3 components:

1. assessment of tasks performed - usually calculating the weighted average of accepted tasks;
2. activities not accepted have a 0 (for these activities, the teacher gives hints for the correct solution);
3. assessing students' individual contribution by analyzing the team's Scrum board.

In the Sprint retrospective students discuss key points of the solved tasks and make a brief report of what went well; what went wrong; what should be improved in the next Sprint.

ALGAN lessons' plans

Beginning of the lecture

Lecture description: In this lecture, the second of the 1st semester, we introduced new concepts, emphasized important aspects of the theory, and studied some solved examples and exercises to be done by the students. The covered were elementary row operations and rank of a matrix. The material for this lecture is displayed on Moodle platform in the week before.

- **Lecture Time:** 10 : 10 – 11 : 00 a.m
- **Lecture Data:** 27/09/2017
- **Lecture Room:** B301
- **Related Terms:** Linear Equations; Decomposition; Linear System; Augmented Matrix; Elementary Matrix; Identity Matrix; Linear Combination; Nonsingular Matrix; Upper Triangular Form

– **Learning Outcomes:** The students should be able to perform the following outcomes:

- Perform row operations on a matrix
- Determine equivalent matrices
- Determine the rank of matrix
- Define the concept of dimension and how to use the rank
- Apply row pivotal condensation method.

The teacher began the lecture by making a little introduction of 5 minutes, with the theme "Elementary Row/Columns Operations", then students are going to do the activities 1 and 2.

A1-Activity 1 (15 minutes)

The first activity is related to the first sub-theme of the lecture: Elementary row operations and equivalent matrices. Looking back, the Jigsaw method is a grouping strategy in which the members of the class are organized into "home groups". The students are then reorganized into "expert" groups containing one member from each home group. The members of the "expert group", work together to learn the material or solve the problem, then return to their home groups to share their learning. In this way, the work of the expert groups is quickly disseminated throughout the class, with each person taking responsibility for sharing a piece of the puzzle. We distributed the different tasks among students:

- Home group1 stays with elementary Row Operation: Operation 1 (2minutes);
- Home group2 stays with elementary Row Operation: Operation 2 (2minutes);
- Home group3 stays with elementary Row Operation: Operation 3 (2minutes);
- Home group4 stays with the equivalent Matrices (2minutes).

In each home group students must study and analyze each task allocated to them, which means that each elementary row operation will be distributed for each home group. Then the students must explore the example given in the slides for the elementary row operations theme.

All students that have been studying the same subtopic, go to the expert groups, during more or less 2 minutes, where they are going to think on possible consequences and doubts about the subtopic.

The groups are then reconfigured into home groups; the experts take turns teaching their specialty to their home group so that each group learns about every topic. This task has the duration of two minutes.

During 4 to 5 minutes, students are challenged to prove their knowledge, with three exercises.

A2-Activity 2 - (35 minutes)

Until now we spent 20 minutes of the lecture, and we are now moving on to activity 2, that lasted approximately 35 minutes. The theme was rank of a matrix. In this activity the home groups are going to be divided accordingly to different items, see:

Home group

- Home group1 Linear Combination of Rows (3 minutes);
- Home group2 Definition of Linearly Dependent Rows; Definition of Linearly Independent Rows (3 minutes);
- Home group3 Rank of a matrix (3 minutes);
- Home group4 Rank of a matrix applying the row pivotal condensation method (3 minutes);

All students that have been studying the same subtopic, go to the expert groups, during more a less 3 minutes. There, they think on possible consequences and doubts about the specific subtopic.

Expert group - 3minutes

- All home group1 stays with **Linear Combination of Rows** (*Think on possible consequences and doubts that they might have*)
- All students2 that study **Definition of Linearly Dependent Rows; Definition of Linearly Independent Rows** (*Think on possible consequences and doubts that they might have*)
- All students3 that study **Rank of a matrix** (*Think on possible consequences and doubts that they might have*)
- All students4 that study **Rank of a matrix applying the row pivotal condensation method** (*Think on possible consequences and doubts that they might have*)

The groups are then reconfigured into home groups; the experts take turns teaching their specialty to their home group so that each group learns about every topic. This task had the duration of two minutes.

Questionnaires

03/09/2020 JigSaw/eduscrum Methodology

JigSaw/eduscrum Methodology

According to the JigSaw/eduscrum methodology applied in curricular unit of Linear Algebra and Analytical Geometry 2017/18, please answer the following survey.

1 In this curricular unit, when the teacher asked you to do an exercise, how did you react?

	Almost never	Seldom	Sometimes	Often	Very often
I disliked the activity and voiced my objections.	☐	☐	☐	☐	☐
I rushed through the activity, giving minimal effort	☐	☐	☐	☐	☐
I tried my hardest to do a good job	☐	☐	☐	☐	☐
I talked with classmates about other topics besides the activity	☐	☐	☐	☐	☐
I felt the time used for the activity was beneficial	☐	☐	☐	☐	☐
I surfed the internet, checked social media, or did something else instead of doing the activity	☐	☐	☐	☐	☐

2 In this course, when the teacher asked you to do an exercise, how did the teacher behave?

	Almost never	Seldom	Sometimes	Often	Very often
Clearly explained what I was expected to do for the activity	☐	☐	☐	☐	☐
Solicited my feedback or that of other students about the activity	☐	☐	☐	☐	☐
Used activities that were the right difficulty level	☐	☐	☐	☐	☐
Walked around the room to assist me or my group with the activity, if needed	☐	☐	☐	☐	☐
Encouraged students to engage with the activity through his/her demeanor	☐	☐	☐	☐	☐
Gave me an appropriate amount of time to engage with the activity	☐	☐	☐	☐	☐

3 With respect to the number of exercises proposed in the practical classes:

	I didn't complete any exercises on time	I completed very few exercises on time	I completed some exercises on time	I completed almost all exercises on time	I completed all exercises on time
	☐	☐	☐	☐	☐

4 Please rate your level of agreement with the following items:

	Strongly disagree	Disagree	Slightly agree	Moderately agree	Strongly agree
Overall, this was an excellent course	☐	☐	☐	☐	☐
Overall, the instructor was an excellent teacher	☐	☐	☐	☐	☐

5 In your opinion, does working in groups enhance your learning skills?

	Strongly disagree	Disagree	Slightly agree	Moderately agree	Strongly agree
	☐	☐	☐	☐	☐

<https://moodle.isep.ipp.pt/mod/questionnaire/print.php?gid=406&id=0&courseid=5726&sec=1> 1/4

Figure 23: General Questionnaire Page1

03/09/2020 JigSaw/eduscrum Methodology

6 Among peers, are you resilient when facing difficulties in some exercises in practical classes?

Strongly disagree Disagree Slightly agree Moderately agree Strongly agree

7 * In your opinion, can the eduscrum methodology help you to develop soft skills for your future professional life?

Strongly disagree Disagree Slightly agree Moderately agree Strongly agree

8 For each of the following things, please indicate how often you did each thing in this curricular unit.

	Almost never	Seldom	Sometimes	Often	Very often
Listen to the teacher lecture during class	☐	☐	☐	☐	☐
Brainstorm different possible solutions to a given problem	☐	☐	☐	☐	☐
Find additional information not provided by the teacher to complete the assignments	☐	☐	☐	☐	☐
Work in assigned groups to complete homework and other projects	☐	☐	☐	☐	☐
Make individual presentations to the class	☐	☐	☐	☐	☐
Be graded on my class participation	☐	☐	☐	☐	☐
Assume responsibility for learning material on my own	☐	☐	☐	☐	☐
Discuss concepts with classmates during class	☐	☐	☐	☐	☐
Be graded based on the performance of my group	☐	☐	☐	☐	☐
Solve problems in a group during class	☐	☐	☐	☐	☐
Solve problems individually during class	☐	☐	☐	☐	☐
Answer questions posed by the instructor during class	☐	☐	☐	☐	☐
Ask the instructor questions during class	☐	☐	☐	☐	☐
Do hands-on group activities during class	☐	☐	☐	☐	☐

Team work

Regarding the team work in **practical classes**, answer the following questions:

9 Team work has helped me to better understand the contents of the course.

Strongly disagree Disagree Slightly agree Moderately agree Strongly agree

<https://moodle.isepp.ipp.pt/mod/questionnaire/print.php?qid=406&rid=0&courseid=5726&sec=1>

Figure 24: General Questionnaire Page2

03/09/2020 JigSaw/eduscrum Methodology

10 The sprints have helped me to better understand the contents of the course.

Strongly disagree Disagree Slightly agree Moderately agree Strongly agree

Opinion

Eduscrum methodology versus Traditional methods of teaching

11 Please fill the following table according to the eduscrum methodology (1=Strongly disagree, 2=Disagree, 3=Slightly agree, 4=Moderately agree, 5=Strongly agree)

	1	2	3	4	5
Communication	☐	☐	☐	☐	☐
Self-motivation	☐	☐	☐	☐	☐
Leadership	☐	☐	☐	☐	☐
Responsibility	☐	☐	☐	☐	☐
Teamwork	☐	☐	☐	☐	☐
Problem solving	☐	☐	☐	☐	☐
Ability to work under pressure and time management	☐	☐	☐	☐	☐
Flexibility	☐	☐	☐	☐	☐
Negotiation and Conflict resolution	☐	☐	☐	☐	☐

12 Please fill the following table according to the Traditional methods of teaching (1=Strongly disagree, 2=Disagree, 3=Slightly agree, 4=Moderately agree, 5=Strongly agree)

	1	2	3	4	5
Communication	☐	☐	☐	☐	☐
Self-motivation	☐	☐	☐	☐	☐
Leadership	☐	☐	☐	☐	☐
Responsibility	☐	☐	☐	☐	☐
Teamwork	☐	☐	☐	☐	☐
Problem solving	☐	☐	☐	☐	☐
Ability to work under pressure and time management	☐	☐	☐	☐	☐
Flexibility	☐	☐	☐	☐	☐
Negotiation and Conflict resolution	☐	☐	☐	☐	☐

13 * Do you agree with the learning by doing method in the practical classes?

Strongly disagree Disagree Slightly agree Moderately agree Strongly agree

<https://moodle.isepp.ipp.pt/mod/questionnaire/print.php?qid=406&rid=0&courseid=5726&sec=1>

Figure 25: General Questionnaire Page3