Journal of Engineering Education Transformations ,
Volume 35 , No. 3 , January 2022 , ISSN 2349-2473, eISSN 2394-1707

Car Race - an Engaging Interdisciplinary Python Based Project Activity

Sandra Gaspar Martins[1,2]
[1]CICS-NOVA,Universidade Nova de Lisboa, Colégio Almada Negreiros | Campus de Campolide 3.º piso - Sala 333 1070-312 Lisboa, Portugal
[2]Departamento de Matemática, Instituto Superior de Engenharia de Lisboa, Instituto Politécnico de Lisboa, Rua Conselheiro Emídio Navarro, 1
[1]sicgm@campus.fct.unl
[2]sandra.gaspar.martis@isel.pt

Abstract: Here we present and evaluate a Calculus project using Python and parametrizations: the CarRace. Each student picks an image of a circuit and another of a car online to make the car perform a race in the circuit. Because every student gets a different circuit, they have different lines to parametrize. This is performed using a Python program. Beforehand students get an example of the code for a car performing a circuit and must adapt it to their own project.

This project was posed to a total of 346 engineering students over the course of 3 years. To evaluate the effectiveness of the project, we surveyed all participating students and 120 of them answered. The feedback from the students was mostly positive. It was engaging for students to make this project. They liked to see an immediate application of Mathematics. It helped them understand the subject better and they found it interesting to combine Python and Mathematics. At the same time, they also develop their critical thinking and problem-solving skills.

Keywords: python, interdisciplinary, engineering students, project, coding, calculus.

Sandra Gaspar Martins
CICS-NOVA,Universidade Nova de Lisboa,
Colégio Almada Negreiros | Campus de Campolide 3.º piso - Sala 333 1070-312 Lisboa, Portugal
sicgm@campus.fct.unl

1. Introduction

The relevance of coding is widely spread. Sullivan and Melvin (2016) state that writing code is fundamental to Science Technology Engineering and Mathematics (STEM) students so they can be literate 21st century scientists. According to Tranquillo (2015) programming is in the curricula of nearly all engineering departments. Also, STEM employers advise students that it is crucial to know how to code, to develop interdisciplinary skills, and to learn to work intensively on a project (Cline et al., 2020; Dorff, 2014). "Computer programming and mathematical algorithms are natural partners in the development of programming skills, logical thought, and a deeper understanding of mathematical concepts" (Jones and Hopkins, 2019). Rich et al. (2014) studied the impact that learning computer programming has on the way students approach mathematics and found that it leads students to get better context, applications, structure, and motivation for mathematics, which are long-lasting apprenticeships. According to Patil and Kale (2019), learning problem solving skills using computer programming in the first year of the degree is important. Moreover, computer aided topics serve to increase interest and promote thinking (Clark,1999).

Project Based Learning (PBL) is an innovative approach for Integrating 21st century skills (Pawar, Kulkarni and Patil, 2020) like: creativity, communication and presentation, time management, self-assessment, group participation, leadership, and critical thinking skills. According to Chen, Kolmos et all (2019) PBL has been widely adopted in engineering education during the last 40 years because of its effectiveness in improving students' academic knowledge, teamwork skills, communication skills and leadership. PBL not only improves problem-solving abilities but also promotes the development of critical thinking skills, involvement in the team, communication skills, comprehension of reflections, and all of the above mentioned as well as understanding and applying the course content, according to Hegade (2019). For example, Cline et al. (2019) presents several examples of projects for introductory, intermediate, and advanced classes of mathematics. According to them "Projects allow students to recognize that they are capable of using mathematics to investigate complex scenarios. In the end, they are an important part of a student's mathematical growth, helping them to become capable and independent problem solvers."

Regarding the study of Mathematics using a computer, many topics in Mathematics can be taught using computer activities (Mackiw, 1996). For example, in a survey of Algebra students, they favoured computer learning approaches in many different ways (Clark et al. 1999). And according to Hodgson (1995) the use of a programming language led to a deeper understanding and interest in Mathematics.

We chose to use Python as the programming language since it is the one that the degree coordinator considers to be transversal to the whole degree. Moreover, it is widely used as a programming language when mathematics is to be associated and used in the outside world. For example, to Schueller (2019) Python is a ubiquitous programming language, present in academy and in industry. So, he utilised Python programming language to solve a project using mathematics. The inverse is also interesting, utilizing mathematics to teach how to code (Langtangen, 2009). He chose Python as the programming language because it combines remarkable expressive power with clean, simple, and compact syntax. Phyton is even used at a high school level in order to code topics of Algebra, Calculus and Statistics (Saha, 2015). Python is also used as a means to introduce problem-based learning and promote active learning in the classroom (Jeyamala, 2020). Hutchison (2021) also integrated Python into an undergraduate mathematics course.

Programming in Python also fosters Active Learning. We, like Namratha et al. (2018), promoted the interaction among students when they were making the project in order to get an active process of learning. Jeyamala and Abirami (2020) also successfully used Active Learning to teach Python.

The CarRace is especially relevant because it includes coding, which is very important to students nowadays. Additionally, it promotes critical thinking, and it is an opportunity for project-based learning. We know that projects allow students to develop many different skills, as well as to engage in active learning which deepens the understanding of the subject and also to develop problem solving skills. The project allows students to learn Mathematics using a computer which gives them a deeper understanding and interest in Mathematics. This project is especially interesting because it mixes it all.

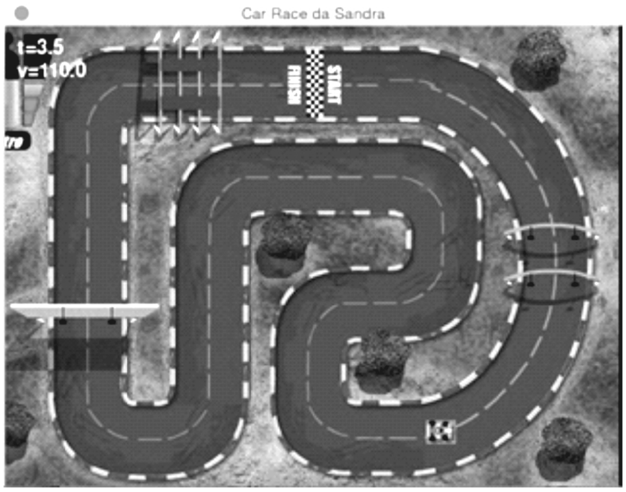
In the next chapter we will show the context in which the project arises. Then, we will explain the project itself. After that, we lay out the research question and the methodology used to collect data. Finally, we will draw our conclusions.

2. Context

In the academic years of 2017/18, 2018/19 and 2019/20 the students of Mathematics Applied to Engineering course of the Computer and Multimedia Engineering degree of a Polytechnic Institute were given a project. This course was a traditional Calculus course for the first year, first semester; the syllabus was differential and integral calculus in IR. That semester, Parametrizations was added to the syllabus. In 2017 the course had 110 students, in 2018 it had 113 students and in 2019 it had 123 students. Respectively, 95, 86 and 99 accomplished the project. The project counted for 10% of their grade, was compulsory and had a minimum grade of 8 out of 20 points. There were 4 classes, two of which had a professor, and the researcher taught the other two. The class size was decided, as usual, by the course manager.

3. Car Race – the project

The goal of the project is to make a car perform a trajectory on a circuit (see Figure 1). Each student searches online for an image of a circuit (or creates it) and then registers it on a page (a wikipage on Moodle) that we called Patent Registry. This way there are no two students using the same circuit, meaning that the



c
i
r

Fig. 1 : Screenshot of a car performing a trajectory on a circuit. The example given to students.

cuit is different to every student. Each student then picks an image of a car. The goal is to make the car perform the trajectory of the circuit using parametrizations. To this end the teacher provides the class with a Python file where a car performs a trajectory: the example code is on Appendix. The Python behind this is quite trivial, the teacher explains how it works in class in 30 minutes and students start their own work in the following 60 minutes. Students need to do little more than to adapt the parametrizations that make the car perform their own race. They perform lines, circles, parabolas, ellipses, etc.

Students only need to take their own laptop with Python and Pygame installed to the class where the example is explained (this is not a problem - every student has their own laptop and they have a programming course where they use Python and Pygame). The circuit must contain at least a line or a parabola and at least a circle or an ellipse to make students learn how to parametrize those kinds of curves. At the end, the student should present the files of the car, the circuit, the Python code and a video of the car performing their race (this may be recorded with mobile phone). Since the project is different for each student, usually students don't need to present it. We only discuss them if we have any kind of suspicion (it has never happened thus far).

The project receives a mark of 10 points if the car runs inside the road. Another 4 points if the velocities are adequately adapted, i.e. runs faster in lines and slower in curves. Another 2 points if the velocity is displayed on the screen. Another 2 points if the car adapts its direction to the trajectory direction. And finally, the other 2 points are afforded to any extra features that the student decides to include.

The aim of the project, more than to evaluate, is to show students an immediate application of mathematics to a natural problem. It is also meant to make Python a transversal tool in their training. Additionally, we look for an engaging problem that students enjoy working on.

4. Data collection

The research question is: Is it possible to create an engaging, multidisciplinary, and effective project to teach mathematics for engineering?

The methodology used was an anonymous survey available to all the 110+113+123=346 students and answered by 26+51+43=120 students.

According to Table 1, students' answers to the question of whether the CarRace project made them pleased or displeased, showed that around 75% felt pleased or highly pleased.

Table 1: Answers to "Working on the CarRace project made me:"

"Working on the CarRace project made me:"	2017	2018	2019
N	26	51	42
Highly pleased	27%	6%	33%
Pleased	42%	68%	48%
Indifferent	16%	22%	17%
Displeased	15%	2%	25%
Highly displeased	0%	2%	0%

According to Table 2, around 50% of the students believed that the project helped them understand the subject better.

Table 2 : Answers to "It helped me better understand the subject:"

"It made me better understand the subject:"	2017	2018	2019
N	26	51	43
Totally agree	4%	4%	21%
Agree	50%	47%	42%
Indifferent	19%	23%	26%
Disagree	23%	24%	7%
Totally disagree	4%	2%	5%

Around 50% of respondents think that using Python didn't increase difficulty to the project (see

Table 3).

Table 3. Answers to "Using Python didn't lead to an increased difficulty:"

"Using Python didn't increase difficulty:"	2017	2018	2019
N	26	51	43
Totally agree	12%	24%	23%
Agree	40%	46%	28%
Indifferent	32%	16%	19%
Disagree	16%	12%	23%
Totally disagree	0%	2%	7%

Very few students disagree that it is important to have Python as a transversal tool in their degree, as can be seen in Table 4.

Table 4 : Answers to "It makes sense to me to use Python transversally in my degree, therefore also in curricular units of mathematics:"

"Using Python transversally in graduation:"	2017	2018	2019
N	26	51	43
Totally agree	32%	26%	30%
Agree	44%	45%	42%
Indifferent	24%	25%	19%
Disagree	0%	2%	7%
Totally disagree	0%	2%	2%

Around 80% of respondents agree that it is important to see an immediate application of mathematics (see Table 5).

Table 5 : Answers to "It was interesting to see an immediate application of Mathematics in CarRace: "

"An immediate application of Mathematics:"	2017	2018	2019
N	26	51	43
Totally agree	27%	22%	35%
Agree	61%	56%	49%
Indifferent	4%	18%	12%
Disagree	8%	4%	4%
Totally disagree	0%	0%	0%

As shown in Table 6, nearly 80% of respondents globally classify the existence of CarRace as positive.

Table 6 : Answers to "Globally I classify the existence of the CarRace project as:"

"Globally I classify the existence of the CarRace project as:"	2017	2018	2019
N	26	51	43
Very good	23%	12%	30%
Good	61%	62%	58%
Indifferent	8%	22%	9%
Bad	8%	4%	0%
Very bad	0%	0%	2%

As qualitative feedback students wrote: "I really loved seeing mathematics be used for something useful, I gained interest to learn more about the subject."; "Good initiative to reconcile UC knowledge in addition to not being too complex, though it still requires dedication and reasoning on the part of the student."; "It makes us debate with other people and research about Python and this leads us to understand and to be more comfortable both with the professors and with the classmates."; "It helped a lot to understand the subject of parameterizations"; "It made me understand more about the subject, in addition to better preparing me for the exam/test. And I really enjoyed seeing my project completed at the end. It was also nice to have the option of being able to choose the map and the icon, as well as the path where he was racing, without having to be the same as the whole class."; "The CarRace concept is an interesting adaptation of parameterization and a good introduction to the theme of autonomous vehicles".

Students were exceptionally committed and

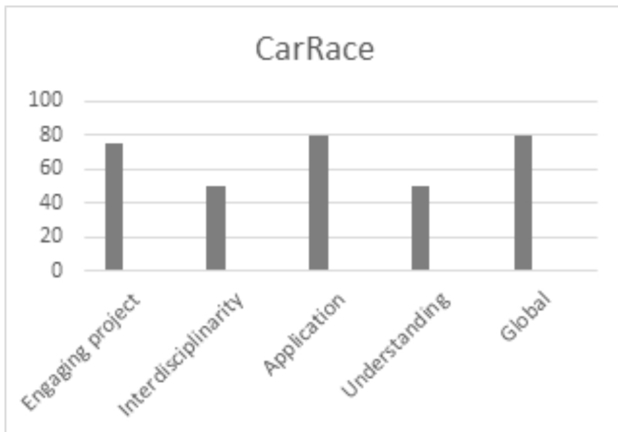


Fig. 2 : Percentage of students who agree that the project is engaging, positive, and interdisciplinarity; that it is positive to se an application of Mathematics; that it deepens understanding, and the global classification as a positive project.

extremely interested in doing the project. They were all paying attention. Students were developing several skills like critical thinking, involvement in the team (after this phase they interact with each other, seeking support), communication skills, problem solving skills, independence, self-learning, etc.

In conclusion, to answer the research question: Is it possible to create an engaging, multidisciplinary, and effective project to teach mathematics for engineering? We can analyse Figure 2.

Regarding "Is CarRace an engaging project?", around 75% of respondents felt pleased doing it.

Regarding whether students perceive its interdisciplinarity as important, around 50% states that using Python didn't increase the difficulty of the project and nearly all students perceive the inclusion of Python transversaly in the degree as important.

Nearly 80% agree that it is important to see an immediate application of mathematics.

Regarding the question of whether it gives students a deeper understanding of the subject, 50% believe that the project made them better understand the subject.

As a global classification nearly 80% classify the CarRace project as a positive activity.

With the qualitative data we can see that: students appreciate to see applications of mathematics; CarRace helped students to gain interest in the subject; CarRace had a good balance of difficulty; it fosters relationships among fellow students and among students and teachers; it deepens the understanding of the subject; and students enjoyed the project. Thus, we can conclude that it is an engaging, multidisciplinary, and effective project.

5. Conclusions

In the first semesters of 2017, 2018 and 2019 a CarRace project using the subject of parametrizations was proposed to 346 computer engineering students wherein each student picked an image of a circuit and an image of a car and made the car perform a race on that circuit. Thus, every student had a different trajectory to parametrize. This was performed using a Python program. Students had access to an example program and adapted it to their own circuit. The project was accomplished by 280 students, which make up 81% of the participating students.

The research question was “Is it possible to create an engaging, multidisciplinary, and effective project to teach mathematics for engineering?” A survey was available to all the students and 120 answered it. More than 75% of respondents stated that they enjoyed doing the project. So, we can conclude that students enjoyed the project.

Around 50% didn't find increased difficulty by doing the project in Python. Nearly all students believe that it is important to have Python transversally present in their degree. Around 80% state that is relevant to see an immediate application of Mathematics. Thus we conclude that students find it relevant to have this interdisciplinarity through the project.

About 50% believe that CarRace helped them learn the subject better. And the global assessment of the project was, according to 80% of respondents, that it is a positive activity.

This project made students develop several skills like critical thinking, teamwork, communications skills, problem solving skills, independence and self-learning.

References

[1] Chen, J., Kolmos, A., Guerra, A., & Zhou, C. (2019). Aalborg UNESCO Certificate: Staff Development and Challenges in PBL Training Programme. Journal of Engineering Education Transformations, 33(1), 13-21. DOI: 10.16920/jeet/2019/v33i1/149002

[2] Cline, K., Fasteen, J., Francis, A., Sullivan, E., & Wendt, T. (2020). A vision for projects across the mathematics curriculum. PRIMUS, 30(4), 379-399. DOI: 10.1080/10511970.2019.1600176

[3] Clark, J. M., Hemenway, C., St. John, D., Tolias, G., & Vakil, R. (1999). Student attitudes toward abstract algebra. Problems, Resources, and Issues in Mathematics Undergraduate Studies, 9(1), 76-96. DOI: 10.1080/10511979908965918

[4] Dorff, M. (2014). Nonacademic careers, internships, and undergraduate research. Involve, A Journal of Mathematics, 7(3), 303-313. DOI: 10.2140/involve.2014.7.303

[5] Hegade, P. (2019). One-Day Many-Problems: A Problem Based Learning Approach. Journal of Engineering Education Transformations, 33(1), 119-124. DOI: 10.16920/jeet/2019/v33i1/149020

[6] Hodgson, T. (1995). Reflections on the use of technology in the mathematics classroom.

Problems, Resources, and Issues in Mathematics Undergraduate Studies, 5(2), 178-191. DOI: 10.1080/10511979508965785

[7] Hutchison, G. R. (2021). Integrating Python into an Undergraduate Mathematics for Chemists Course. In Teaching Programming across the Chemistry Curriculum (pp. 123-134). American Chemical Society. DOI: 10.1021/bk-2021-1387.ch009

[8] Jeyamala, C., & Abirami, A. M. (2020). Enhancing Student Learning and Engagement in Freshman Course on Problem Solving Using Computers. Journal of Engineering Education Transformations, 33, 192-200. DOI: 10.16920/jeet/2020/v33i0/150144

[9] Jones, L. B., & Hopkins, B. J. (2020). Teaching a course in mathematical programming. PRIMUS, 30(5), 571-600. DOI:10.1080/10511970. 2019.1619207

[10] Langtangen, H. P. (2009). A primer on scientific programming with Python. Springer Berlin Heidelberg. https://link.springer.com/book/10.1007\%2F978-3-642-54959-5

[11] Mackiw, G. (1996). Computing in abstract algebra. The College Mathematics Journal, 27(2), 136-142. DOI: 10.1080/07468342.1996.11973766

[12] Namratha, M., Rekha, G. S., Akram, S., Kumar, S. S., & Nayak, J. S. (2018). Active Learning Approach for Python Programming. Journal of Engineering Education Transformations, 32(1), 15-19. DOI: 10.16920/jeet/2018/v32i1/130803

[13] Pawar, R., Kulkarni, S., & Patil, S. (2020). Project Based Learning: An Innovative Approach for Integrating 21st Century Skills. Journal of Engineering Education Transformations, 33(4), 58-63. DOI: 10.16920/jeet/2020/v33i4/139423

[14] Patil, J. A., & Kale, S. P. (2019). Impact of ICT Tools in Logic Development of Computer Programming Skills. Journal of Engineering Education Transformations, 33(1), 7-15. DOI: 10.16920/jeet/2019/v33i1/139182

[15] Prensky, M. (2008). Programming is the new literacy. Edutopia magazine. http://www.edutopia.org/ literacy-computer-programming

[16] Rich, P. J., Bly, N., & Leatham, K. R. (2014). Beyond cognitive increase: Investigating the influence of computer programming on perception and application of mathematical skills. Journal of Computers in Mathematics and Science Teaching, 33(1), 103-128. https://www.learntechlib.org/primary/p/41965

[17] Saha, A. (2015). Doing Math with Python: Use Programming to Explore Algebra, Statistics, Calculus, and More!. No Starch Press.

[18] Schueller, A. W. (2020). Phone Sensor Data in the Mathematics Classroom. PRIMUS, 30(7), 790-801. DOI: 10.1080/10511970.2019.1639864

[19] Sullivan, E., & Melvin, T. (2016). Enhancing student writing and computer programming with LATEX and Matlab in multivariable calculus. Primus, 26(6), 509-530. DOI: 10.1080/10511970.2015.1122688

[20] Tranquillo, J. (2015). Coding to Think: Teaching Algorithmic Thinking from Idea to Code. Journal of Engineering Education Transformations, 28(4), 23-32. DOI: 10.16920/jeet/2015/v28i4/70386

Appendix: CarRace code

```
# Import pygame module
import pygame, sys
from pygame.locals import *
from math import cos, sin, sqrt
# inicialization of pygame module
pygame.init()
# creation of a window
width = 532
height = 410
size = (width, height)
window = pygame.display.set_mode(size)
pygame.display.set_caption('Car Race da Sandra')
```

```
    #window'name
#At this window the (0,0) point is at upper left corner
#and (532-1,410-1) = (531,409) is at the lower right
    corner.
# number of frames per second
frame_rate = 30
# clock to control frame rate
clock = pygame.time.Clock()
# read an image
speedway = pygame.image.load("speedway.jpg")
car = pygame.image.load("car.jpg")
#Inicializes time
t=0.0
##########################
#To write the time in the top of the window
font_size = 25
font = pygame.font.Font(None, font_size) # default
    font
antialias = True # suavization
WHITE = (255, 255, 255)# color (values of Red,
    Green, Blue between 0 and 255)
###########################
##Example adjusted to circuit:
def parametrization (t):
  if t==0:
    result=(230,40)
  if 0<t<=0.5:
    result=(230+250*t,40)
  if 0.5<t<=3.64:
    result=(355+110*cos(-2+t),190+150*sin(-2+t))
  if 3.64<t<=4:
    result=(347.4-250*(t-3.64), 339.6)
  if 4<t<=4.4:
    result=(250, 340-250*(t-4))
  if 4.4<t<=4.8:
    result=(250+250*(t-4.4), 230)
  if 4.8<t<=5.2:
    result=(355, 230-250*(t-4.8))
  if 5.2<t<=5.6:
      result=(355-500*(t-5.2), 120) #around twice
    velocity
  if 5.6<t<=5.9:
      result=(160, 140+500*(t-5.6)) #around twice
    velocity
  if 5.9<t<=6.4:
    result=(120+450*(t-5.9), 340-(450*(t-5.9)**2))
    #around twice velocity
  if t>6.4:
    result=(0,0)
  return result
##################################
#Main cycle of the game
while True:
  time = font.render("t="+str(t), antialias, WHITE)
  window.blit(speedway, (0, 0))
  window.blit(car, parametrization(t))
  window.blit(time, (10, 10))
  pygame.display.update()
  clock.tick(frame_rate)
  t=t+0.1
    for event in pygame.event.get():
    #To quit...
    if event.type == QUIT:
      pygame.quit()
      sys.exit()
    #When to click on any place, the time restarts on
    t=0
    # event mouse click left button (code = 1)
##    elif event.type== pygame.MOUSEBUTTONUP
    and event.button == 1:
##          t = 0
```