Learn&Fly: engaging students in STEM via aeronautics

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Abstract. Learn&Fly is an Erasmus+ project aimed to demystify and to crack STEM subjects to youngsters by showing their importance and application in aeronautics. Concepts in physics and maths are explained by engagement in the construction of an aircraft, aimed to compete in a flight contest. Students must envisage, design, draw and calculate the craft, simulate its flight, make necessary design adjustments, and build it. In its first year the project attracted 121 students, between 17-21 years old; 19.5% were girls. Students work on the glider was accompanied by lectures in physics, materials, and technologies. A questionnaire was used to quantify students’ perception on project usefulness. Results show that students considered the project to be effective in improving STEM skills and career awareness, and very effective in improving soft skills. This is expected to result from the stimulating, hands-on STEM learning environment that provided access to contents, tools, and activities not usually available to high school students from the partaking countries.

1. Introduction
Science, Technology, Engineering, and Mathematics (STEM) are everywhere. The Science component of STEM builds and systematizes knowledge on the physical universe via natural and formal sciences [1]. Technology is the sum of techniques, methods and processes used in production activities. Engineering is the goal-oriented process of designing and making systems to exploit natural phenomena for practical purposes, and is directly related to problem solving and innovation [2]. Every STEM area channels mathematics (a formal science), to handle quantities, structures and space [3]. STEM knowledge is essential for personal progress on problem solving, abstract reasoning and critical thinking. It is also mandatory for societal development, by providing a qualified workforce able to drive countries to meet their economic needs and global competitiveness [2]. A number of countries (e.g. Japan, Taiwan, Singapore, Australia) have been articulating national STEM policies, strategies and programs [4]. Yet, that is not the general case in Western Europe, where underachievers in science reached 20.6% of students in 2018 [5]. In that context, increasing school accomplishment and STEM
literacy has become a priority of the European Union. Learn&Fly was funded as part of such agenda, via the Erasmus+ program. Learn&Fly include teams from Poland, Portugal, and Spain, originating from the higher education, industrial and corporate areas. These countries are persistently affected by STEM underachievement, with 16.3-23.8% of students bellow 15 years old failing to reach basic skills level. Also, none of them has a comprehensive and coordinated governmental strategy for pre-college education in STEM. In this context, Learn&Fly proposes to benefit from informal learning to increase students’ interest in STEM [6,7]. Aeronautics is used to trigger such interest because powered flight represents an amazing technological achievement, requiring huge technical and technological capability and the crossing of knowledge in a range of STEM subjects, including math, computer science, physics, materials, electronics, automation, control, mechanics, among many others. Also, flight fascinates most youngsters, possibly because of the freedom and mystery it conveys, associated to the charm and social appraisal of aeronautic-related professions. Learn&Fly proposes to intersect those features to encourage and empower students to pursue STEM studies and professions.

2. Methodology
The Learn&Fly approach is to explain STEM concepts by engaging students in hands-on activities related to the construction of a functional aircraft, aimed to compete at national (1st stage) and international (2nd stage) flight contests. Students are enrolled in the frame of Aeronautics Clubs created in high schools, where they work in teams of 2-4, supervised by a teacher. Each team plans the necessary design and construction tasks according to the flight competition schedule and regulation. This includes to envisage, design, draw and calculate the aircraft, simulate its flight, make necessary adjustments to initial design, build it, and fly it. Construction is chronologically accompanied by lectures by the teacher framing all necessary theoretical knowledge and practical techniques required. Lectures use a set of dedicated slides with alluring design, divided in 7 modules: Brief History of Flight; Materials; Basics of Flight; Processes and Technologies; Technical Drawing; Aircraft Design; and Simulation (Fig. 1a).

![Figure 1](image_url)

Figure 1. Students’ Kit contents. (a) Slides of the Basics of Flight module: cover page (top) and the concept of centre of gravity concept applied to aircraft balance (bottom); (b) Excel sheet provided for aircraft calculation.

Overall, the Project package encompasses 5 tools:

- **Students’ STEM Kit.** Comprises the slides used for the lectures, an Excel spreadsheet to calculate the glider model (Fig. 1b), and a set of simple materials to start glider construction (Fig. 2a) (also, selection/reuse of available simple materials for construction is encouraged).

- **Teacher’s STEM Kit.** Contains the slides plus the Notebook for Teachers, a simple guide to support teachers on implementing Learn&Fly in class. It aims to assist teachers in subjects that are not part of their academic background, allowing them to prepare lectures quickly and easily, even if not familiar with a particular course.
- **Gamification and digital access.** The full Learn&Fly package is available on project site (http://learn-fly.eu/) and Moodle platform, where gamification¹ was implemented. It consisted in quizzes to test acquired knowledge, awarded with extra-launches in the flight competition.

- **Flight Competition.** Competing with the built aircraft in a flight contest is the ultimate goal to accomplish by the teams. The first stage of the competition takes place each country, between national teams. In the second stage, national winning teams participate in the international competition; at this point teams can improve their projects, including propelling forces (Fig. 2b).

- **Careers Kit.** It’s a dynamic on-line database (lodged on the website) that comprehensively lists jobs and career opportunities in the aeronautic, air transport and flight operation industries. It aims to be a career-counselling support tool for students, parents, teachers, and vocational counsellors. Each profession includes description of task and working conditions; required education/training path and duration; comprehensive list of awarding institutions in each country; and updated employment statistics. Around 150 testimonials of professionals in the field are also rendered, listing personal views on the hardships, challenges, and rewards of each aeronautical career.

Aeronautics experts in the 3 countries were consulted throughout Kits elaboration, to make them as oriented as possible to the real needs of the aeronautics industry. Globally, the main outcomes expected for the students result as follows:

- To design the aircraft, students need to understand the main aircraft structural components (fuselage, wings, stabilisers, ribs) and applied forces (lift, weight, thrust, drag). This involves knowledge on statics and dynamics, and mathematical skills.

- Students use a flight simulator (X-Plane, Laminar Research) to design and optimize the aircraft. The program simulates the forces and moments acting upon the designed model, evaluates their effect applied to lift and drag of the whole virtual aircraft, and then puts it to fly [8]. This allows students to improve their craft iteratively and easily, since the simulator immediately illustrates how it would perform in the real world.

- Some starting materials are provided in the Students’ Kit, yet others are needed to optimise and finish construction. Students must judiciously select them (based on the lecture on the range of materials currently used in aeronautics), knowing that two criteria must be met: low density, and resistance to applied loads during flight.

- Students contact traditional hobby-modelling techniques that can be used in glider construction (e.g., plastics hot string cutting), are trained in 3D printing to be able to produce customised plastic and foam parts for the craft and are lectured in state-of-art aeronautics manufacturing technologies.

- Efficient planning, systematic development of required tasks and appropriate dates costs monitoring are mandatory for teams to reach the competition stage on schedule, rendering management skills.

- Students must develop communication skills: oral and written presentations are evaluated in competition stages; ability to listen and be listened is mandatory to accomplish results in teamwork.

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¹Gamification is the process of incorporating game elements (points, medals or levels, for example) in a non-game context, to increase users’ engagement [15].
3. *Learn&Fly’s First Edition*

Project kick-off took place in November 2017 and the call for students was launched in November 2018. During that time the kits were assembled and local implementation in enrolled high schools took place. Each partner locally provided dedicated training to high school teachers and assured permanent support to enlighten doubts and worries, and to incorporate adjustments according to schools’ reality. In the following school year students’ teams assisted lectures, built their gliders, and prepared for competition. National contests took place on May and June 2019: in Portugal (Fig. 3a) the competition was won by *Sebastião da Gama High School* (Setúbal), in Spain (Fig. 3b) by *Instituto Tecnológico Superior* (Seville), and in Poland (Fig. 3c) by *Nicolaus Copernicus High School* (Mielec); winning gliders respectively flew 28.7, 16.7 and 53.6 m.

![Figure 3. National competition in (a) Portugal; (b) Spain; and (c) Poland.](image)

The international competition took place in the frame of an international mobility week, from 16-20 September 2019 in the *Aviation Valley* (Podkarpackie), Poland. Students and their teachers visited aviation companies operating in the region and the Podkarpackie Science Festival. They shared experiences and approaches to aircraft construction and were able to improve their projects (Fig. 4a). The week culminated in the *Learn&Fly* international competition. The competing aircrafts (now with propeller) were first presented and defended before a jury including industry, local government, and academy representatives (Fig. 4b). The flight competition then took place, in the *Jasionka International Airport* grounds (Fig. 4c). It was won by the Polish team (Fig. 4d), with 57.4 m flight distance. The 3 teams in the international competition were awarded money prizes (courtesy of Pratt&Witney).

![Fig. 4. International competition: (a) the three contending aircraft (from left to right Portuguese, Spanish and Polish); (b) Portuguese team presentation to the jury; (c) aircraft launch by the Spanish team; (d) the winning Polish team (supervisor teacher on the left).](image)

A questionnaire was prepared and distributed to the students, to characterise the sample population and to assess students’ opinion on the project and their perception of its effect on their STEM and soft skills. Besides 13 questions requiring a numerical answer (Table 1), there was also an open question asking an opinion on the Challenge: “In what way did the Learn&Fly Challenge enabled you the most”?
Ultimately this leads girls to self-censorship and low engagement in STEM. It is thus of great importance to address the underrepresentation of girls and of underachievers is in line with abundant reports from other authors, e.g. [9–11], and expected to result mostly from lack of personal motivation. It should be mentioned that inequalities such as low socioeconomic status or geographical distance (that often create and reinforce that underrepresentation [12]) were not relevant in Learn&Fly enrolment, since activities took part in school grounds, during school hours, and all expenses were covered by the project.

**Figure 5.** Students’ self-evaluation in STEM (Question 4): (a) global; (b) by country; (c) by gender.

Female participation in the Project is below statistics reporting 33% of female students worldwide in STEM areas [13]. This suggests that STEM education remains an area of gender disparity in the partaking countries, where the gap between male and female in STEM becomes evident at the early stages of school education and increases while growing up, sharpening at late adolescence [14]. This is mostly because societal bias triggers young girls’ lack of confidence in their maths, science and information technologies abilities, and depreciates their expectations of careers in those fields [13,14]. Ultimately this leads girls to self-censorship and low engagement in STEM. It is thus of great importance...
that projects such as Learn&Fly tackle the low representation of girls in STEM education and subsequently of women in STEM professions [11].

Answers to Question 5 show that students had great fun learning about and building their own aircraft. Apparently, boys (4.6±0.4) enjoyed it a little more than girls (4.3±0.9), while there is no significant difference between the three participating countries nor between participants’ age.

Students’ opinion on the STEM Kit was assessed with Questions 1 to 3. None found “understanding of STEM topics” or “glider construction” very difficult, but 26.8% thought “simulation” was so (Fig. 6a). On the other hand, 24.2, 9.8 and 9.8% of the students respectively found STEM, simulation, and construction very easy. Results by country approx. follow the same trend (Fig. 6b). Girls and boys found equally easy to understand the math and physics underlying flight and to carry out simulation, yet girls (2.9±0.6) found aircraft construction more difficult than boys (2.4±0.8) (Fig. 6c).

**Figure 6.** Students’ opinion on easiness in accomplishing project activities (questions 1 to 3): (a) globally; (b) by country; (c) by gender. (Answers from 1: very easy, to 5: very difficult).

Students’ perception on STEM skills improvement was assessed with questions 6-8. Math is where students felt the project was less useful, while physics and science in general were the ones felt more useful (Fig. 7a). Project usefulness to STEM achievement was apparently more valued by Polish (3.5±0.0) and Portuguese (3.0±0.3) than by Spanish students (2.4±0.6) (Fig. 7b). Girls found the project less effective in improving their STEM skills than boys (Fig. 7c), especially concerning math.

**Figure 7.** Students’ opinion regarding project effectiveness on improving their math, physics, and science skills (Questions 6, 7 and 8, respectively): (a) globally; (b) by country; (c) by gender. (Answers from 1: very low, to 5: very high).

Students’ perception on soft skills improvement was assessed with questions 9, 11, 12 and 13. Average marks on improvement are very similar (Fig. 8a), respectively 4.0±0.4 (team cooperation), 3.9±1.1 (active participation in group decision), 3.8±1.0 (flexibility to change opinions) and 3.8±0.5 (cognitive...
awareness and flexibility). Polish and Portuguese students considered that their main personal achievement regarded group participation (4.8±0.2 and 4.2±0.4, respectively), while Spanish students consider having especially improved their cooperation skills (4.3±0.4) (Fig. 8b). On average, both girls and boys felt the ability to intervene and participate in group decisions as their main personal conquest (respectively 4.4±0.1 and 4.3±0.4) (Fig. 8c). Interestingly, answers to the open question reinforced students increased awareness regarding improvement of their soft skills: teamwork; responsibility to share tasks; assertiveness to stand for my opinion; ability to compare results; share ideas; finding my strongest ability; healthy competition; find good solutions to problems were the most used expressions to adjective the project.

Fig. 8. Students’ opinion regarding project effectiveness on improving their soft skills (Questions 9, 11-13): (a) global; (b) by country; (c) by gender. (Answers from 1: very low, to 5: very high).

The effect of the Careers Kit in raising awareness of aeronautical professions was assessed by answers to Question 10. Students classified with 3.3±0.9 the effect of the project on their career knowledge (Fig. 9a). Polish (4.1±0.7) and Portuguese students (3.5±1.1) felt the more enlightened, while Spanish students were somehow disappointed (2.3±0.7) (Fig. 9b). Despite this large span, globally 36 and 24% of the students respectively found the project “very useful” and “extremely useful” in enlightening possible career paths in aeronautics. Interestingly, answers’ analysis by age (Fig. 9b) shows a strong decrease between the 15-17 (3.8±0.1) and the 18-19 (2.8±0.7) age range. This is probably because at this age youngsters have defined their career choices and are already preparing for college admission.

Figure 9. Students’ opinion on raised awareness regarding professions in aeronautics (Question 10): (a) globally; (b) by age.

5. Final Remarks
Being a student-centred, problem-based project Learn&Fly is expected to increase students’ motivation. A measure of students’ compliance to this project was the volunteering of some participants to tutor at the Aeronautics Clubs established in their high schools. Also, before any kind of official publicity and based only on participants testimonial to their friends and colleagues, enrolled high schools receive a
total 56 pre-registrations from students interested in the 2020 edition. This was prevented by the COVID19 pandemics, but a 2022 edition is already taking form. The project was also expected to impact participant teachers, increasing their motivation to hands-on experimental projects, entrepreneurship education and cooperative interdisciplinary approaches. Accordingly, informal talks with the involved teachers revealed that they very much enjoyed delivering the classes, because they found their work with the students “more natural” (sic) by working side by side with them, not necessarily supervising but rather providing them answers.

6. Conclusion
This paper describes the Learn&Fly project approach to motivate active and participative STEM learning by high school students. Instead of the traditional approach of unilateral transmission of scientific knowledge, the project steers students to the active practice of science, through participation and cooperation in the design and construction of an aircraft. Students’ perception on the project seems to support the followed approach and suggest that the created aeronautics-related learning environment provided context and drive for the learning of STEM subjects, while improving soft skills. The low percentage of STEM underachievers recruited results that this research mostly concentrated on students who have already entered STEM fields. In next editions, students’ recruitment actions will especially focus this target group an also female students, both underrepresented in the Project’s reported edition.

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