Innovative learn-by-doing digital education and attitudes towards STEM: an RCT in Italian high schools*

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Abstract

We conducted a randomized controlled trial to test the effectiveness of creative STEM activities on the propensity to enrol in a STEM university course and career aspirations on a sample of 710 high school students in Italy. The activities covered courses on 3D printing, laser cutting, and programming, and were taught by FabLabs, non-profit digital fabrication laboratories with an innovative pedagogical approach grounded in learn-by-doing, problem-solving skills, and creativity. Participation in the activities was voluntary, but counted for credit. We find that access to these courses increased students' intentions to pursue STEM majors at university (6 p.p., +17%) and STEM careers (7.4 p.p., +40%), possibly through to an increased STEM self-efficacy (7.3 p.p., +22%), namely students' beliefs in their ability to pursue STEM studies.

Keywords: STEM, university choice, digitalization

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1 Introduction

Recent technological progress and automation are profoundly transforming the demand for labour. While highly educated workers are generally advantaged, only skills that are complementary to digital technologies are safe from the threats of automation. These skills are typically STEM-oriented, analytical, non-repetitive, and engage with complex problem-solving and creative thinking, implying a high degree of adaptability to rapidly changing labour markets (Black et al., 2021; Lassébie and Quintini, 2022; Acemoglu and Restrepo, 2019, 2018).

From a policy perspective, this creates the double challenge of increasing the number of STEM major graduates while also equipping them with soft skills that enhance long-term adaptability. At the same time, however, the supply of STEM graduates loses students at several steps of the education process (a "Leaky pipeline", Wickware, 1997). Secondary education curricula worldwide struggle to include the use of modern digital technologies to a sufficient degree (OECD, 2020), potentially decreasing the attractiveness of STEM majors among high school students. Later on, not all STEM graduates transition into STEM occupations, especially in the case of women (Meoli et al., 2024). Indeed, while the undersupply of STEM professionals concerns both sexes, a large literature has shown that attracting women into STEM is particularly challenging, further contributing to the gender gap in wages and employability (e.g., Jiang, 2021; Charlesworth and Banaji, 2019).

In this paper, we test whether creative STEM activities offered to high school students can increase their interest in pursuing STEM university studies and a career in STEM-related fields. Within a field experiment in Italian high schools conducted in the 2021-2022 academic year, we randomly offered different classes the possibility to participate for credit in activities run by FabLabs, organizations that adopt a learning-by-doing pedagogical approach in teaching the use of digital fabrication tools, and whose activities are grounded in fostering creativity, collaboration, and problem-solving. Originally established by the Massachusetts Institute of Technology (MIT) in the early 2000s, FabLabs are now diffused worldwide, both as independent laboratories and within schools, universities, and corporate R&D departments (Oppedisano, 2024). In our trial, students are trained to use FabLab equipment (3D printers, laser cutters, and CNC milling machines) and software (3D modeling and coding) to bring their ideas to life, solving an actual problem rather than learning mnemonically. Specifically, these tools were used to design and build robots equipped with sensors to interact with the environment, low-cost microscopes for the school, new benches for the local park, and replicas of local sculptures.

Our sample consists of 710 students from 5 high schools in Italy. To account for spillover effects, we randomize access to FabLab activities at the class level (42 classes). Nevertheless, we conduct our analysis at the individual level to leverage the detailed student-level baseline information: at the beginning of the school year and before randomization, we conducted a baseline survey covering pre-treatment attitudes towards going to university, enrolling in STEM majors, and career aspirations, as well as parental educational attainment, field of specialization, and job occupation. The survey was conducted in class, and the data were then integrated with school administrative records on students' GPAs. Since 137 students were absent from school on the date of the baseline survey and thus had missing baseline information, they were excluded from the final analyses, resulting in a final sample of 573 individuals.

At the beginning of the 2021-2022 school year, students in the treated group were offered to join the FabLab STEM activities, whereas those in the control group could only choose alternatives unrelated to STEM. In both cases, the activities count as "PCTO" credits ("*Percorsi per le competenze trasversali e l'orientamento*"), required by law for all high school students and linked to internships, extra-curricular courses, or social work meant to orient students in the labor market. For treated students, we kept track of actual enrollment in FabLab courses using administrative records from both the schools and the FabLabs. At the end of the school year, we conducted a second survey to measure outcomes.

FabLab activities differ from previously studied interventions and adopt an innovative approach to target factors that are theoretically linked to the choice of STEM majors and careers. Analyzing over 470 studies on the determinants of women's (under)-representation in science, Avolio et al. (2020) underline the importance of fostering (i) Individual factors – such as perceived self-efficacy and attitudes toward science (see also Scott and Mallinckrodt, 2005), (ii) Labour factors – such as the lack of information on possible career types, (iii) Educational factors – academic performance, beliefs about what skills are required for a STEM career, and the pedagogic approach in teaching STEM subject that can reinforce negative attitudes (see also Blickenstaff, 2005) (iv) Social factors – in particular, the perceived possibility of being socially useful as a STEM professional (see also Sax et al., 2016).

Previous studies on secondary education focused on increased curricular exposure to STEM subjects (Black et al., 2021; De Philippis, 2023), that mostly act through academic performance and interest in STEM subjects, and exposure to role models (e.g., Breda et al., 2023; Biroli et al., 2025), which provide information on possible career types in practice – those represented by role models – and potentially act on self-efficacy. FabLabs add an innovative learn-by-doing pedagogic approach and teach a wide range of practical skills that can be applied creatively to a potentially unlimited number of ideas, including those with a direct social impact. A famous example was the adaptation of snorkeling masks into life-saving ventilation masks during the COVID-19 pandemic, carried out in an Italian FabLab (Maci, 2020); in our interventions, students' creations contribute to their schools and communities. Moreover, students learn malleable skills to practically solve a problem during FabLab activities, and get to know a collaborative reality that they can also follow after the intervention: this can have a different impact on perceived self-efficacy compared to more traditional curricular activities and is linked to sustained effects in the long term (Bailey et al., 2017).

The experiment is carried out in Italy, a setting that can particularly benefit from similar interventions. The Italian context is historically characterized by a low tendency to innovate (Colombo and Delmastro, 2002). However, Routine Biased Technological Change – the tendency of replacing human labor with machinery in performing repetitive and programmable tasks – is as relevant as in the rest of the industrialized world: digital-intensive employment of highly skilled workers is growing, but only through non-repetitive, creative and cognitive tasks that face a lower risk of being automated (Cirillo et al., 2021). Consequently, in this context, digital entrepreneurship that exploits creative skills to create intellectual property has a higher potential of surviving negative economic shocks (Khlystova and Kalyuzhnova, 2023). Young innovative firms in Italy – characterized by a prevalence of SMEs – are more likely to thrive if the founder has more years of education in economics or sciences and technology or previous technical experience in the industry (Colombo and Grilli, 2005). Yet, Italy is the second-worst country in the European Union for enrollment in tertiary education, and this negative trend is driven especially by male students (Eurostat, 2025a). Despite being more likely to prefer STEM majors conditional on enrolling in tertiary education (e.g., Xie et al., 2015; Jiang, 2021; Ceci et al., 2014), and being more represented than females, the share of male STEM graduates in the population is substantially lower than European figures (Eurostat, 2025b).

We find that offering FabLab activities does not impact the intention to attend university, but increases the intentions to pursue a STEM profession by 7.4 percentage points (a 40% increase relative to baseline). Indeed, accounting for the overall uncertainty of attending university at all, intentions to pursue STEM-related majors at university increase by 6 percentage points (equivalent to a 17% increase). The effects are potentially driven by increased self-efficacy, namely, students' beliefs in their ability to engage with and perform tasks related to STEM fields, which increased by 7.3 percentage points (equivalent to a 22% increase relative to baseline). Consistent with previous interventions studied in the literature, male students drive the observed effects, whereas for females, we detect a smaller and less precise effect on intentions to pursue STEAM studies. STEAM comprises STEM plus digital-intensive artistic fields (e.g., interior design), suggesting that the creative component of FabLabs may generate interest in some female students.

Our design allows voluntary compliance – i.e., enrollment in FabLab courses, if given the possibility – to mirror actual conditions of *PCTO* credits in the Italian schooling system. However, female students are less inclined towards STEM to begin with. From a policy perspective, our analysis of compliance based on the availability of alternative courses across schools indicates that compulsory attendance of these creative STEM activities may be more beneficial to address the future intentions of girls. Nevertheless, the effect on male students is also of interest for policymakers, given males' overall lower likelihood to pursue university studies and lower self-efficacy. In the Italian context, an additional challenge is the structural lack of STEM graduates. At the same time, voluntary attendance through the already established PCTO credit system is easily implementable and scalable from a policy perspective.

To our knowledge, this is the first attempt to assess the causal effect of learn-by-doing creative STEM activities in secondary schools on attitudes towards university, STEM studies, and STEM careers. A vast body of observational literature has instead focused on the determinants of choosing a STEM major, especially among women. In their review of US-based studies, Xie et al. (2015) find that while socioeconomic background matters for attending university in general, social-psychological factors are relatively more important in defining whether students pursue a STEM major. Indeed, our analysis suggests that self-efficacy is the main mechanism through which FabLab activities increase the intention to choose a STEM major; relatedly, in a companion paper, we also find positive effects of our intervention on grit and externally validated creativity (Ballerini et al., 2024).

Inventive STEM activities and their impact on career choices are the focus of a growing literature on universities and young adults. Dalziel and Basir (2024) find that exposure to brief inventive activities based on practical learning leads to technological imprinting in *de novo* entrepreneurs, namely those business owners who did not inherit or buy their company but rather created it themselves. In Italy, besides the aforementioned Colombo and Grilli (2005), Colombo and Piva (2020) show that curricula specialized in limited scientific and technological fields foster subsequent entrepreneurship (i.e., academic spin-offs). Finally, Del Carpio and Guadalupe (2022) randomized an informational campaign on upcoming coding courses aimed at adult, low-income women in Peru and Mexico that also included access to a female role model. They find higher enrollment rates through improved self-efficacy and mitigated gender stereotypes about science and technology.

Most studies on secondary schools focus instead on existing curricula. Black et al. (2021) and De Philippis (2023) find that increased exposure to curricular mathematics and sciences classes increases interest in pursuing STEM majors. Joensen and Nielsen (2018) find causal evidence that older siblings who choose a math-science major influence the major choice of younger siblings. These studies also find more prominent effects for male students.[1] Qualitative studies also suggest that curricular interventions based on technological making workshops – similar to our intervention – increase students' proficiency and interest in design and engineering tasks, and more generally in STEM subjects (Kafai et al., 2014; Berland, 2016; Bevan, 2017).

The paper proceeds as follows: Section 2 describes the institutional context, Section 4 describes the experimental design, the treatment, and the outcomes, Section 5 details the empirical strategy, Section 6 presents the main results. We conduct heterogeneity by sex and discuss potential mechanisms Section 6.2. Finally, Section 7 concludes the paper.

2 Institutional context

2.1 The Italian school system and university enrollment statistics

Our paper examines the impact of the FabLab pedagogical approach in a sample of upper-secondary schools in Italy. The Italian education system is structured into three main levels: primary education, lasting five years (ages 6 to 11); lower secondary education, lasting three years (ages 11 to 14); and upper secondary education, which covers ages 14 to 19.[2] While primary and lower secondary schools are characterized by a rather strong standardization of curricula, upper secondary education is marked by higher curricular differentiation (Ballarino and Panichella, 2021).

At the age of 14, students are required to choose among several educational tracks. The most prestigious among these are the academic-oriented schools (*licei*), which typically enroll the highest-achieving students and provide a better preparation for university studies (Triventi et al., 2021). In contrast, vocational schools (*istituti professionali*) aim at training students for manual occupations in the service and industrial sectors. Technical institutes (*istituti tecnici*) offer specialized training in fields such as mechanics, electronics, and business management, aiming to facilitate both direct entry into the labor market and access to higher education, even

[1]Another branch of the literature focuses on the "gender gap" in school math scores, finding that females' worse performance is driven both by an aversion for competition that is induced by tests (Niederle and Vesterlund, 2010; Ors et al., 2013), and can result from cultural factors transmitted across generations (Nollenberger et al., 2016). O'Dea et al. (2018) test the alternative explanation that females' test scores are less dispersed and more concentrated around the mean: as a result, there are fewer female students with exceptionally high math grades. They find that while the dispersion in STEM subjects is lower for female than for male students, this is not enough to explain the gender gap in choosing STEM majors.

[2]3-years vocational courses are chosen by a small minority of students and will not be discussed here.

if they are considered less academically demanding than *licei*.

Despite these differences, all tracks confer eligibility for university admission. Nevertheless, different tracks place varying emphasis on specific curricular subjects, potentially affecting the ability to pursue university studies in specific fields. Only a minority of subjects (e.g., mathematics, Italian, English) are present in each curriculum, even if with a varying degree of intensity. Within each educational track, there are internal subdivisions: the *licei* are primarily distinguished by the relative weight given to STEM disciplines versus the arts and humanities (e.g., *licei scientifici* have a higher focus on STEM disciplines in contrast to *licei classici* focused on traditional humanities; *licei linguistici* focus on foreign languages and *licei artistici* on arts); the focus of *istituti tecnici* can be either on business-related or on technical fields; while the *istituti professionali* vary between care-related and technical subjects (Contini et al., 2025). Tertiary education is more homogeneous: unlike in countries with dual academic–vocational systems, Italy delivers almost all tertiary education through universities, with limited short post-secondary vocational options (Ulicna et al., 2016).

Tracks and sub-tracks in high schools exhibit a notable segregation on the basis of students' sex and social origins. Empirical evidence highlights considerable social homogeneity within schools and classrooms (Barone et al., 2021): *licei* predominantly attract students from highly educated families and the upper classes; *istituti professionali* mainly serve students from less educated and frequently migrant backgrounds; while *istituti tecnici* occupy an intermediate position on the socio-economic gradient, as they are conceived as a viable alternative to students who are not sure whether to continue to university after the diploma.

As a result, a system that formally grants access to university to all students with a five-year upper-secondary school diploma generates distortions in university enrollments. As shown in Table 1, actual university enrollment rates remain relatively low compared to other European countries—both in the overall working-age population (Panel A) and among younger generations (Panel B), with only modest improvements over time. This represents an ongoing policy challenge. This outcome is influenced mainly by the fact that only students from *licei* pathways tend to perceive themselves as sufficiently prepared to undertake university, resulting in overall low self-efficacy. Specific to the Italian context, instead, male enrollment rates are especially disadvantaged, displaying a wider educational gender gap compared to the European average. A similar gap in comparison with the rest of Europe is also evident for the field of study: the share of STEM graduates in the young working population (20-29) is in line with the EU averages for females (approximately 15%), but much lower for males – 22% in Italy *vs* 29% in the EU (Eurostat, 2025b). More detailed statistics on graduates by field and country are reported in

Figure A.1 in the Appendix.

Table 1: Italy *vs* EU averages: 2023 educational attainments by age and sex of the students

	Panel A: Full working-age population (ages 15-64)					
	% Low educational attainment			**% High educational attainment**		
	Total	**M**	**F**	**Total**	**M**	**F**
EU avg	24.7	26.0	23.4	30.9	28.1	33.7
Italy	36.7	39.3	34.2	19.2	16.1	22.7
	Panel B: Post-university young population (ages 25-34)					
	% Low educational attainment			**% High educational attainment**		
	Total	**M**	**F**	**Total**	**M**	**F**
EU avg	14.5	16.4	12.6	43.1	37.6	48.8
Italy	19.9	23.0	16.6	30.6	24.4	37.1

Notes: The data were obtained by Eurostat (2025a). Low educational attainment corresponds to having completed at most lower-secondary school (levels 0-2 of the International Standard Classification of Education). High educational attainment corresponds to tertiary education, i.e., university studies (levels 5-8 of the International Standard Classification of Education).

Summarizing, Italy stands out in Europe for having an overall low university enrollment rate; the share of STEM graduates is especially low among males although, in absolute numbers, female STEM graduates are less than males, similar to other countries. In other words, the lack of STEM graduates in Italy represents an ongoing and particularly relevant policy challenge, since STEM studies are rarely chosen also by males, who display higher STEM enrollment rates in other countries.

An important candidate determinant of this situation is the early tracking of students, since families already choose tracks when enrolling in high school. One of the mechanisms through which students sort into different educational tracks is the guidance provided by the teaching board in the final year of lower secondary school (middle school). This consists of a non-binding recommendation. While formally intended to support informed and merit-based decision-making, empirical research has consistently shown that such recommendations are not neutrally formulated, and depend instead on the students' socioeconomic status, ethnic background (Romito, 2016; Checchi, 2010), or sex (Manzella, 2023). In particular, those from more affluent or highly educated families are more frequently encouraged to enrol in academically-oriented *licei*, while female students are disproportionately steered toward tracks with lower exposure to STEM subjects compared to their male peers *(ibidem)*. These disparities are especially pronounced among students with average academic achievement, where the discretionary nature of guidance advice becomes more salient (Romito, 2016).

2.2 FabLabs

FabLabs (namely, fabrication laboratories) are small-scale workshops that offer access to tools for digital fabrication and adopt a hands-on pedagogical approach. This concept was created at the Massachusetts Institute of Technology (MIT) in 2002 when digital fabrication tools, including 3D printers, CNC machines, and electronics, were packaged in a standardized low-cost lab (Blikstein and Krannich, 2013). The founder of the FabLab concept, Prof. Neil Gershenfeld, describes this digitalization of fabrication as the process "where you do not just digitize design, but the materials and the process" (Solon, 2013), so digital fabrication has the mission of "bringing programmability to the real world". FabLabs projects, which have now spread in educational and entrepreneurial contexts all over the world, range from jewellery to furniture and all the way up to entire houses (Ferracane, 2020).

FabLabs began projects in primary and secondary education in 2008 thanks to Stanford University's FabLab@School project, with a specific focus on incorporating the "making" into school curricula. The pedagogical approach is based on "playful experimentation", i.e., the practical use of tools and materials to make the learning experience more engaging (Regalla, 2016). The specific activities offered by FabLabs in our study are described in Section 4.1.

3 Sample composition and summary statistics

Students who participated in the program were enrolled in five different Italian high schools, from grade 10 (the second year in the upper-secondary school cycle) to grade 13 (the fifth and last year).[3] The five schools – each one associated with a different FabLab – are located in different cities in the North, Center, and South of Italy: Schio, Verona, Mantua, Ancona, and Agrigento. A map illustrating the geographic location of each city is presented in Figure A.2, in the Appendix. Among the schools contacted by FabLabs and that decided to be part of the experiment, the vast majority are of two types: technical school (*istituto tecnico*) and arts school (*liceo artistico*).[4] In both cases, FabLab courses complement their curricula. In fact, although their curricula place greater emphasis on practical subjects than other schools, they

[3] Specifically, 10th graders accounted for 58.1% of the analysis sample, 11th graders 7.1%, 12th graders 17.1%, and 13th graders for 17.6%. Considering instead the initial sample – i.e., including students who were absent on the day of the baseline survey – 10th graders account for 57.7% of the analysis sample, 11th graders 8.87%, 12th graders 17.0%, and 13th graders 16.3%.

[4] One school has three classes with a scientific major *(liceo scientifico)*, whose curriculum is specialized in mathematics and sciences: two of these are assigned to treatment.

do not include the specific skills taught in FabLab activities (e.g., 3D printing, laser cutting, programming). On the other hand, these schools exhibit enrollment rates in university below the average (especially in STEM subjects), and attract the students who middle school teachers and families deem to be the least likely to follow university studies, as discussed in Section 2.1.

Table 2 presents summary statistics for the 573 students for whom we observe baseline characteristics and conduct our analyses. Our sample comprises slightly more males than females. Most students have both parents employed, but with generally low educational attainment (only one third of students have at least one parent with tertiary education). Slightly less than half of the students want to enroll in university, but the share decreases when considering STEM faculties: despite approximately 40% reporting an interest in studying STEM at university, only 23% intend to do so, possibly due to low self-efficacy, revealing a group of students who can ex ante potentially benefit from the FabLab course intervention.

Table 2: Summary statistics pre-treatment

	Mean	SD	Min	Max	N
Female (=1)	0.38	0.48	0.00	1.00	573
No Siblings (=1)	0.17	0.38	0.00	1.00	573
Age	16.53	1.31	14.00	22.00	573
First Born	0.51	0.50	0.00	1.00	573
Either Parent Working (=1)	1.77	0.43	0.00	2.00	573
Either Parent University (=1)	0.34	0.47	0.00	1.00	573
University (=1)	0.44	0.50	0.00	1.00	573
STEM University (=1)	0.41	0.49	0.00	1.00	573
Self-Reported Ability STEM University (=1)	0.34	0.47	0.00	1.00	573
Self-Reported Interest STEM University (=1)	0.41	0.49	0.00	1.00	573
Self-reported GPA	7.21	0.98	0.00	10.00	573
Self-Reported interest STEM Prof Carrer (=1)	0.25	0.44	0.00	1.00	573
Favorite Subject is STEM in High School (=1)	0.52	0.50	0.00	1.00	573
Least Preferred subject is STEM in High School (=1)	0.41	0.49	0.00	1.00	573

Note: The Table displays summary statistics for our analysis sample, comprising 573 students for whom we observe baseline survey answers.

4 Experimental design

This section describes in detail the stratified experimental design, our treatments and outcomes, following our pre-registered analysis plan, which is available at the AEA RCT registry, trial number 8407 (Dominici et al., 2025). Any deviations from the pre-analysis plan are noted in the text and in Section B of the Appendix.

4.1 Treatment

Fablab activities covered in our study were conducted between September 2021 and May 2022. They were carried out in each school by instructors employed by the local FabLab since, as detailed in Section 4.3, randomization is carried out within each school, and the analysis is stratified by school.[5] However, all FabLab instructors received the same formation from the investigators and applied the same pedagogical approach. Moreover, the contents of the activities were designed and managed centrally by Fondazione Edulife, meaning they are harmonized across the participating FabLabs[6].

All the FabLab activities offered as part of our study lasted approoximately 25 hours and share a learning-by-doing approach in teaching the use of digital fabrication tools (e.g., 2D and 3D modelling, 3D printing, laser cutting), group work, an informal and relaxed learning environment, playful activities, and a learning model based on peer-to-peer interactions and aimed after a specific, self-contained project. In other words, all the involved students learned to use digital fabrication tools creatively to solve actual problems or build something of practical use, often involving the wider local community, rather than studying mnemonically (Resnick, 2017; Ferracane, 2020) – a pedagogical model rarely adopted in Italian high schools.

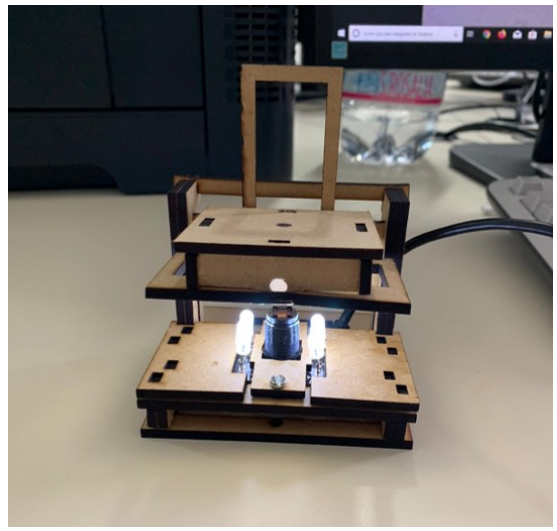
While these features were common to all the FabLab courses, the specific project varied across FabLab-school pairs – corresponding to strata in our experimental design. In Verona, students built low-cost microscopes for their school using common objects (wood cuts and webcams), resorting to digital fabrication for their assembly (Figure 1**B.**). In Schio, digital fabrication was aimed at building robots that could interact with the surroundings through the creation and application of sensors. In Mantua, students learned photogrammetry (a technique used to extract measurements and 3D information from photographs, to be used as input for 3D modelling and printing) to create replicas of statues from the local monumental cemetery (Figure 1**C.**). In Ancona, students learned 2D modelling and used CNC milling machines and laser cutting to create benches that were eventually placed in the local park, structuring the design phase with consideration of both the practical construction of the benches and their decorations, and the needs of final users (Figure 1**A.**). Finally, in Agrigento, digital modeling techniques were used to design the decorations of T-shirts, which were eventually realized with laser cutters and digital embroidery machines.

[5] We also include school fixed effects in our main analysis, which will also capture the variation brought by different FabLab educators.

[6] As part of the Fabschool project funded by Fondazione Cariverona.

Figure 1: Examples of FabLab courses' outputs

(A.) Ancona: benches



(B.) Verona: microscopes

(C.) Mantua: cemeterial statues

4.2 Outcomes

We focus on three different families of primary outcomes: attitudes towards STEM, university choice, and career aspirations.[7] Being of a subjective nature, all outcomes were self-reported and measured both at baseline and endline via surveys carried out individually by each student, in class, under the supervision of investigators and instructors. The full text of both the baseline and endline questionnaires is reported in Section D in the Appendix.

Attitudes towards STEM We measured attitudes towards STEM subjects with two questions. The first was aimed at detecting the interest of the students in this possibility: "At university, would you be interested in taking STEM courses?", followed by a reminder of what fields of study are classified as STEM. The second, instead, was aimed at detecting self-efficacy in case of an enrollment in a STEM field: "If you went to university, would you feel able to follow/take a course in STEM subjects?" Both of these questions could be answered in a binary form (yes/no).

University Choice Intentions We test whether human capital decisions are altered by FabLab activities. We expect students may shift their intentions towards pursuing university education, and, more specifically, STEM courses at university. The intentions to attend university, and in which field, could be altered at both the intensive and extensive margins. Namely, it could affect both students who were undecided regarding studying at university and steered towards enrollment following our intervention, or students who wanted to enrol in non-STEM different majors who updated their preferences following FabLab courses. Taking this distinction into account, we collected two measures of university choice: we first asked students whether they wished to enrol in university, and then asked them to indicate all the potential fields of study. We coded as STEM fields the following options in our survey, corresponding to ISCED-13 codes 05, 06, 07, the standard STEM study field classification (UNESCO Institute for Statistics, 2015): engineering, information technology, biology, physics, astronomy, mathematics, architecture, earth sciences, computer sciences, and chemistry. Finally, we created a binary variable equal to one if a STEM field was selected. Given the emphasis on artistic creation and design in the proposed FabLab activities, as a secondary exploratory outcome, we also repeat the

[7] In our Pre-Analysis Plan, we did not distinguish between attitudes towards STEM and University choices, and grouped them together under the label of "Interest in STEM subjects". Instead, we included preference over school subjects as a pre-registered outcome, meaning only Mathematics. Given the nature of FabLab courses and pedagogical approach, and later insights, we still maintained three families of outcomes, but we: (i) Omitted preference for mathematics, which is, however, available upon request; (ii) Distinguished between attitudes towards STEM, meaning interest and perceived self-efficacy, which can be seen as intermediate outcomes, and actual intentions to pursue university studies, and if so, whether in a STEM field.

analysis considering STEAM rather than STEM, namely including design-oriented studies (e.g., industrial and interior design), which now routinely employ digital design tools.

Career Aspiration Finally, we assessed the intention to pursue STEM careers through open-ended questions. We first asked students if they had ideas about their future job and, subsequently "If yes, what job do you imagine", in the form of an open question.[8] We then asked more specifically: "Imagine yourself as an adult. Realistically, what job do you think you will do?". We used the latter question to build our outcome variable on career aspirations, since it was aimed at eliciting realistic aspirations.[9] In our main classification, we classified jobs into two categories: STEM professionals versus other professions, according to the taxonomy developed by the 2014 Occupational Outlook Quarterly, U.S. Bureau of Labor Statistics (Vilorio, 2014). STEM professionals are individuals aiming at a STEM-related job that requires a tertiary degree in a STEM field. Following best practice, each open answer that required classification has been independently coded by two of the authors of this paper. In the first round of coding, we reached a level of agreement higher than 95%. The few disagreements were resolved by a third coder, chosen from the other authors of this paper.[10] Given the peculiarity of the FabLab experience and the presence of students from artistic school tracks, also for this outcome we built a secondary indicator that expands the definition of STEM jobs by also adding artistic jobs that require a technical component, thereby creating the STEAM category.[11]

4.3 Randomization, balance and attrition

The final sample used in our analyses consists of 573 students in 5 schools, comprising 42 classes. They were surveyed twice: once at the beginning of the school year and once at the endline, after FabLab courses had taken place. The reason we only use part of the full sample of 710 students is that we observe baseline characteristics necessary for our model estimation only for these 573. While every student observed at baseline is also observed at endline (i.e., we had no attrition in the common sense), there are 137 students out of the initial 710 for whom

[8] This first question was also asked in the baseline questionnaire and used as a control variable in our regressions, to increase estimates' precision and power.

[9] The results are very similar when building the outcome using the former question (results available by request to the authors).

[10] The full taxonomy is freely accessible at `https://www.bls.gov/careeroutlook/2014/spring/art01.pdf`.In case of ambiguous answers (e.g., "*electronic*"), we took advantage of the field of study and of the likelihood of enrolling in university in the coding procedure. In case of multiple jobs listed (e.g., "*Engineer, surgeon*"), we coded the job as STEM if at least one of the occupations listed could be classified as such. We included among STEM jobs "Commander of the Navy", since this job position in Italy requires a University-level degree in marine engineering.

[11] In the STEAM category we included the jobs "interior designer" and "photographer".

we only observe endline answers: this "inverse" attrition is due to absence from school on the day of the baseline survey, or to a missing or wrong name in either survey, which prevents the match. We could test for systematic differences between our analysis sample ($N = 573$) and these excluded subjects ($N = 137$) only in those time-invariant characteristics that are not affected by treatment, which we can extract from the endline survey: sex, parental education and occupational status, whether the student has siblings and whether he/she is the firstborn. We found two significant differences, although small in magnitude: students excluded from the analysis were more likely to be male (difference in means equal to 0.18, $p = 0.00$) and to have no siblings (difference in means equal to 0.09, $p = 0.01$). Given males' higher interest in STEM, this potentially imposes a downward bias on our estimates, making them conservative.[12] Most importantly, and in line with the notion that missed matches were due to random school absences, this "inverse" attrition is not correlated with treatment status.[13]

We randomize treatment at the class level, within schools. The class-level probability of assignment to treatment is equal to 0.7, which results in 28 treated classes (409 students) and 14 control classes (164 students). The 42 classes are distributed in 5 schools/cities (see Figure A.2 in the Appendix). We test balance in baseline covariates and show the results in Table 3. The tests are performed by estimating the following model for every covariate X_k with $k = 1, \dots, K$:

$$X_{k,i} = \alpha_{0,k} + \alpha_{1,k} Treat_i + \alpha_{2,k} School_i + \eta_{k,i}, \qquad i = 1, \dots, N,$$

where $Treat_i$ takes value 1 if student i belongs to a treated class, and 0 otherwise.

As displayed in Table 3, randomization manages to equalize baseline characteristics except for one covariate, a binary indicator for whether the student's favourite subject in school is a STEM subject. In particular, treated students are less likely to report STEM subjects as their favourite. Similarly to potential spillovers between treated and control classes within the same school – untestable – this imbalance could, if anything, make our estimates more conservative by introducing downward bias. In any case, we adjust for all the covariates measured at baseline to control for this difference.

[12]We conducted the test by testing for a difference in means between the two groups. In practice, we regressed each variable on a binary indicator equal to one if the student was part of our final sample. For the variables parental tertiary education, number of employed parents, and whether the student is firstborn, p-values were equal to 0.61, 0.21, and 0.26, respectively.

[13]The bivariate OLS coefficient is 0.05, with a p-value of 0.29.

Table 3: Balance Table

Covariates	Control Mean	Difference ($\widehat{\alpha}_{1,k}$)	P-value
Female (=1)	0.366	-0.019	0.790
No Siblings (=1)	0.171	0.015	0.661
Age	16.744	-0.234	0.120
First Born	0.524	-0.018	0.719
Number of Parents Working (0-2)	1.787	0.002	0.955
Either Parent University (=1)	0.317	0.032	0.460
Wants to enroll in University (=1)	0.384	0.068	0.254
Wants to enroll in STEM University (=1)	0.409	0.012	0.798
Self-Reported Ability STEM University (=1)	0.396	-0.054	0.373
Self-Reported Interest STEM University (=1)	0.445	-0.032	0.432
Self-reported GPA	7.133	0.106	0.229
Self-Reported interest STEM Prof Career (=1)	0.232	0.034	0.494
Favorite Subject is STEM in High School (=1)	0.622	-0.107	0.032
Least Preferred Subject is STEM in High School (=1)	0.470	-0.049	0.338

Note: $\widehat{\alpha}_{1,k}$ is a difference in means obtained by regressing each covariate on the binary treatment indicator and on a series of school dummies. The p-value corresponds to its T-test for the regression coefficient $\widehat{\alpha}_{1,k}$ being equal to zero.

5 Empirical strategy

For each outcome variable, we estimate the Intention to Treat effect (ITT) with clustered linear regressions. In this setting, the ITT is the effect of the possibility of accessing FabLab activities, namely, being randomly assigned to treatment.[14]

We estimate the following model:

$$Y_{h,i} = \beta_{0,h} + \beta_{1,h} Treat_i + \boldsymbol{\gamma}_h \boldsymbol{X_i} + \varepsilon_{h,i} \tag{1}$$

Where Y_h denotes one outcome in the vector of outcomes $\boldsymbol{Y}$. Our parameter of interest is β_1, estimating the average ITT. Standard errors are clustered at the class level, namely the level of assignment to treatment, following Abadie et al. (2022). $\boldsymbol{X}$ is a vector of baseline covariates, which includes a set of school (stratum) fixed effect dummies, the number of parents who are active workers, the student's age and three other dummies indicating whether (i) student i is a male; (ii) any of the two parents of student i obtained a university degree; and (iii) student i was the first child. In order to increase statistical power and to correct for the slight imbalance

[14]Our pre-analysis plan initially foresaw the estimation of a Local Average Treatment Effect by Two-Stages-Least-Squares, Instrumental Variable, but the final number of clusters and characteristics of compliance made that choice unfeasible. A more detailed discussion of deviations from the Pre-Analysis Plan is available in Section B in the Appendix.

in baseline attitudes towards STEM that derives from having a limited sample, we also include baseline outcomes: willingness to attend university, self-reported interest in STEM majors, self-reported ability to pursue a STEM major, and self-reported GPA.

From a policy perspective, the ITT is informative about the effect of offering students the opportunity to participate in FabLab activities. Since in our setting it was only possible to randomize assignment to treatment rather than treatment uptake, in our pre-registration, we planned to estimate the Local Average Treatment Effect (LATE) by Two-Stage Least Squares (2SLS) regression. This estimand would have identified the effect of FabLab courses for compliers, namely those students that, once randomly given the possibility to follow FabLab activities, actually decided to attend them (approximately 38% of the total). As detailed in B, our pre-analysis plan also foresaw a substantially larger sample, which would have made 2SLS estimation feasible thanks to a lower variance. Moreover, the observed uptake of FabLab courses makes the ITT estimand more viable and interesting for policy due to likely spillovers within classes. Indeed, 38% of eligible students choose to enroll in FabLab courses, but treated students who do not take up the offer may still be influenced by peers who do. Given that classmates often share similar interests and discuss post-secondary plans, it is plausible that participation by some students affects the outcomes of others. In this context, 2SLS estimates based on individual take-up would mix the direct effect of FabLab participation with peer-driven effects, making it difficult to isolate the impact of attending the course. For these reasons, we focus on intent-to-treat estimates, which remain valid even in the presence of such spillovers, and can provide relevant insights regarding education policies as they would actually be implemented in the context under study.

6 Results

6.1 Main analysis

Table 4 summarizes our results on the effect of having the possibility to participate in FabLab courses (ITT estimates). Starting from the outcomes related to university intentions, we find that FabLab courses do not significantly affect the extensive margin—namely, the willingness to pursue higher education (column 1). The estimate is imprecise, hence not significant, due to the limited number of clusters, but it is not small in magnitude: it corresponds to a 3.6 percentage point increase over a baseline of 41% – i.e., a 9% increase. We view this as suggestive evidence that this margin could also be affected in a larger sample, potentially an indication for future studies in this domain. In contrast, we find a stronger and statistically significant effect on the intention to pursue a university degree in STEM (column 2), with an increase of 6.1 percentage points – a 17% rise relative to the baseline. The effect on willingness to enroll in a STEAM faculty (Panel B, column 1) is close in magnitude, albeit less precisely estimated, resulting in a non-significant estimate.

As discussed in Section 4.2, we included the secondary (and exploratory) STEAM outcomes given the emphasis put on creativity by FabLab courses.[15] The fact that the effect is stronger for STEM, as opposed to general enrollment, likely reflects the phrasing of the question on field choice: we ask students which area they would choose if they were to go to university. This conditional structure encourages even undecided students to express a preference. As a result, the effect on STEM is larger than the effect on the extensive margin, and it is arguably driven by students who hold a preference for STEM activities despite still being uncertain about whether to enroll in university.

While one might be concerned that conditional intentions do not necessarily translate into enrollment, two considerations are relevant. First, many students in our sample are not in their final year of high school, which likely exacerbates uncertainty about post-secondary plans and may dampen any effect on university enrollment itself. Second, the magnitude of the effect on the willingness to enroll in a STEM field is substantial: 6.1 percentage points over a baseline of 35% corresponds to a 17% relative increase.

Further support for this interpretation comes from columns 3 and 4 of Panel A, which show that FabLab students report greater self-efficacy in STEM fields, although their stated interest in STEM subjects does not significantly increase. This pattern is consistent with the idea that while students become more confident in their ability to pursue STEM, some remain undecided about continuing their studies after high school. Accordingly, the increase in conditional intentions to study STEM likely reflects growing aspirations among students who are still forming their post-secondary plans. Finally, this growing orientation toward STEM fields also maps into a higher stated probability of pursuing a STEM-related professional career (column 5), with an effect of 7.4 percentage points over a baseline of 18% – i.e., a 41% increase.

Adjusting for multiple hypothesis testing reveals that, for three pre-registered families of outcomes, the significant results on self-reported STEM ability and the willingness to pursue a STEM occupation are robust to a Bonferroni correction at the 10% significance level. The Bonferroni correction is, however, too conservative, as it ignores the positive dependence between our outcomes. Indeed, more positive attitudes towards STEM are instrumental to the pursuit

[15] By exploratory, we indicate that the STEAM reclassification of fields and occupations was not included in our pre-analysis plan.

Table 4: Main Results: Possibility to attend FabLabs, university and occupational attitudes

Panel A: Main outcomes

	Wants to enroll in University (1)	Wants to enroll in STEM faculty (2)	STEM self-efficacy (3)	Interest STEM (4)	Wants to pursue a STEM occupation (5)
Can Attend Fablab	0.036	0.061**	0.073**	0.031	0.074**
	(0.026)	(0.030)	(0.033)	(0.035)	(0.033)
Control Mean	0.409	0.354	0.329	0.360	0.183

Panel B: STEAM outcomes (exploratory)

	Wants to enroll in STEAM faculty (1)	Wants to pursue a STEAM occupation (2)
Can Attend Fablab	0.056	0.046
	(0.033)	(0.032)
Control Mean	0.451	0.244

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
All dependent variables are binary indicators. All specifications control for baseline characteristics: the outcomes measured at baseline, school (stratum) fixed effect dummies, the number of parents who are active workers, the student's age and three other dummies indicating whether (i) student i is a male; (ii) any of the two parents of student i obtained a university degree; and (iii) student i was the first child. Standard errors are clustered at the class level and reported in parentheses. STEAM outcomes in Panel B are secondary outcomes and were not included in our pre-analysis plan.

of university studies in STEM and, eventually, STEM occupations. To account for this positive correlation between outcomes both within and across families, we detail and perform the Benjamini and Bogomolov (2014) false discovery rate procedure in Section E of the Appendix. Despite the relatively limited sample size at our disposal, the primary outcomes in each family remain significant at a 10% false discovery rate. As an additional check, in Section C we repeat the main analysis without controlling for baseline covariates, allowing us to verify the absence of major differences between the analysis sample where covariates are observed ($N = 573$) and the full sample where these are partly unobserved ($N = 710$). All results are qualitatively confirmed despite losing precision, as expected, and the coefficient for STEM occupation remains statistically significant at the 5% level.

6.2 Heterogeneity and exploratory mechanisms

The intervention under study consists of granting access to FabLab courses among mandated extra-curricular activities, leaving the take-up of the course up to students to mirror actual conditions faced by a hypothetical policymaker. In this Section, we explore two important dimensions of heterogeneity from a policy perspective: compliance and students' sex. We also investigate their interplay to assess whether FabLabs can mitigate the issue of women self-selecting out of innovative STEM curricula.[16] In the tables that follow, we do not separate STEM and STEAM outcomes for the sake of conciseness, although, as mentioned previously, STEAM outcomes are exploratory.

In the Italian schooling system, high school students are required to earn PCTO credits through internships or extracurricular courses in order to graduate, but the specific activity choice remains generally free, constrained only by the variety of available activities, which is determined autonomously by each school. In our study and in a real-life scenario, FabLab courses become *de facto* compulsory when other alternatives are limited or absent. This is the situation for two schools in our setting (totalling 106 students), where students in treated classes exhibited perfect compliance: i.e., they all attended FabLab courses when given access to them. Imperfect compliance is instead observed for the remainder of the schools (the majority, as expected, totalling 467 students).

Table 5 estimates our main results separately for schools with imperfect and perfect compliance. Intentions to pursue a STEM profession increase under both imperfect and perfect compliance. In the latter case, the null hypothesis of no effect is only marginally accepted, with a p-value of 0.1, due to the reduced sample size and hence power. Intentions to pursue STEM university studies are also not clearly associated with compliance, with marginally insignificant estimates in both cases. On the other hand, the magnitude of the treatment effect on perceived STEM ability is markedly higher in perfect compliance schools, which seem to drive the overall estimate (0.142 and 0.073, respectively). In Section 2.1, we discussed that students in technical and artistic high school majors are typically those who had lower grades in middle school, and exhibit lower perceived self-efficacy. What can we learn from these results? Possibly, that low self-efficacy at baseline might prevent the take-up of innovative STEM courses, whereas imposing attendance could alleviate self-selection into course enrollment, favoring the exposure to these activities for the students who could benefit the most.

[16]While heterogeneity by sex was pre-registered, heterogeneity by compliance is an exploratory analysis, which we included as an alternative to the pre-registered Two-Stages-Least-Squares, Instrumental Variable analysis. A more complete recount of deviations from our Pre-Analysis Plan is presented in Section B of the Appendix.

With regard to heterogeneity by sex, Table 6 reveals that the effects documented in the previous Section are largely driven by male students. The comparison between column 1 versus column 8 in Table 6 shows that the effect on the extensive margin—willingness to attend university—is positive for male students (4.7 percentage points), and arguably larger than what we observe in the full sample. For female students, by contrast, the estimate is close to zero and precisely estimated, suggesting that the lack of an average effect is not simply due to limited power.

The same pattern holds when looking at the intention to pursue a university degree in STEM. Male students exposed to the FabLab program are 9.1 percentage points more likely to choose a STEM field if they go to university – a 24% increase relative to their baseline – and the effect is statistically significant at the 10% level. For female students, the estimate is again close to zero. Interestingly, the results for STEAM are more nuanced: we observe no effect on STEM for females, whereas the estimate on STEAM is somewhat larger. While still imprecisely estimated, this suggests that some female students may have developed an interest in FabLab activities primarily through their creative component. Related work documents that FabLab participation also enhances self-reported creativity (Ballerini et al., 2024). Taken together, these results suggest sex-specific pathways through which the program operates: the technical aspects of FabLab activities seem to resonate more with male students, while the creative aspects may be more salient for females.

Similarly, the effects on self-reported ability and interest in STEM are concentrated among male students (columns 11 and 12). For them, perceived ability increases by 8.8 percentage points, nearly identical to the effect estimated in the full sample. Moreover, unlike in the pooled analysis, we also observe an increase in interest in STEM subjects among male students, of similar size. Finally, consistent with what we showed so far, the probability of pursuing a STEM professional career increases only for males (column 14). On the one hand, this is not surprising in light of existing studies that attribute sex differences in STEM careers' take-up to preferences. On the other hand, in the Italian setting, we discussed that male students are less likely to pursue higher education, with especially low numbers of STEM graduates (see Section 2.1).

How do students' sex and compliance interplay? In descriptive terms, Figure A.3 in the Appendix reveals that males are more likely to attend when students are free to choose, lending further support to the notion that different preferences for STEM activities drive sex differences. Table 7 reports heterogeneous treatment effects by sex under imperfect compliance.[17] Indeed, intentions to pursue STEM university studies and professions, which were overall statistically

[17] We are prevented from repeating the same exercise under perfect compliance because of the small sample size and the low representation of female students.

significant under imperfect compliance, are driven by male students. This result, in line with the above considerations on heterogeneous effects by compliance, points towards a closer integration of FabLab activities into school planning, in order to foster and encourage participation even from students who would normally opt out of such activities, such as female students. In addition, while we find that the creative activities offered by FabLabs are ineffective on female students, significant effects for male students become especially policy-relevant in the context under study, where males also display suboptimal graduation rates from STEM faculties.

Table 5: Effect of Possibility of Attending FabLab courses on Self-reported University and Career Outcomes: Heterogeneity by Compliance

	Schools with Imperfect Compliance						
	Wants to enroll in University (1)	Wants to enroll in STEAM faculty (2)	Wants to enroll in STEM faculty (3)	STEM self-efficacy (4)	Interest STEM (5)	Wants to pursue a STEAM occupation (6)	Wants to pursue a STEM occupation (7)
Can Attend Fablab	0.022	0.066	0.059	0.052	0.033	0.039	0.076*
	(0.032)	(0.040)	(0.036)	(0.041)	(0.039)	(0.041)	(0.040)
Control Mean	0.395	0.460	0.347	0.306	0.306	0.258	0.177
	Schools with Perfect Compliance						
	Wants to enroll in University (8)	Wants to enroll in STEAM faculty (9)	Wants to enroll in STEM faculty (10)	STEM self-efficacy (11)	Interest STEM (12)	Wants to pursue a STEAM occupation (13)	Wants to pursue a STEM occupation (14)
Can Attend Fablab	0.076*	0.016	0.058	0.142***	0.018	0.081	0.081
	(0.039)	(0.027)	(0.040)	(0.026)	(0.065)	(0.048)	(0.048)
Control Mean	0.450	0.425	0.375	0.400	0.525	0.200	0.200

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

All dependent variables are binary indicators. All specifications control for baseline characteristics: the outcomes measured at baseline, school (stratum) fixed effect dummies, the number of parents who are active workers, the student's age and three other dummies indicating whether (i) student i is a male; (ii) any of the two parents of student i obtained a university degree; and (iii) student i was the first child. Standard errors are clustered at the class level and reported in parentheses. The number of observations was 467 and 106 for Schools with imperfect and perfect compliance.

Table 6: Effect of Possibility of Attending FabLab courses on Self-reported University and Career Outcomes: Heterogeneity by Sex

	Females						
	Wants to enroll in University	Wants to enroll in STEAM faculty	Wants to enroll in STEM faculty	STEM self-efficacy	Interest STEM	Wants to pursue a STEAM occupation	Wants to pursue a STEM occupation
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Can Attend Fablab	-0.005	0.070	-0.007	0.064	-0.030	0.042	0.047
	(0.057)	(0.051)	(0.044)	(0.049)	(0.029)	(0.034)	(0.030)
Control Mean	0.617	0.417	0.300	0.283	0.350	0.233	0.150
	Males						
	Wants to enroll in University	Wants to enroll in STEAM faculty	Wants to enroll in STEM faculty	STEM self-efficacy	Interest STEM	Wants to pursue a STEAM occupation	Wants to pursue a STEM occupation
	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Can Attend Fablab	0.047	0.028	0.091*	0.088*	0.079	0.070	0.105**
	(0.031)	(0.045)	(0.047)	(0.047)	(0.062)	(0.049)	(0.048)
Control Mean	0.288	0.471	0.385	0.356	0.365	0.250	0.202

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
All dependent variables are binary indicators. All specifications control for baseline characteristics: the outcomes measured at baseline, school (stratum) fixed effect dummies, the number of parents who are active workers, the student's age and three other dummies indicating whether (i) any of the two parents of student i obtained a university degree; and (ii) student i was the first child.. Standard errors are clustered at the class level and reported in parentheses.

Table 7: Effect of Possibility of Attending FabLab courses on Self-reported University and Career Outcomes: Heterogeneity by Compliance and Sex of the students

	Schools with Imperfect Compliance - Females						
	Wants to enroll in University	Wants to enroll in STEAM faculty	Wants to enroll in STEM faculty	STEM self-efficacy	Interest STEM	Wants to pursue a STEAM occupation	Wants to pursue a STEM occupation
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Can Attend Fablab	-0.029	0.078	-0.018	0.066	-0.027	0.029	0.035
	(0.063)	(0.056)	(0.048)	(0.059)	(0.029)	(0.035)	(0.032)
Control Mean	0.596	0.404	0.269	0.231	0.288	0.231	0.135
	Schools with Imperfect Compliance - Males						
	Wants to enroll in University	Wants to enroll in STEAM faculty	Wants to enroll in STEM faculty	STEM self-efficacy	Interest STEM	Wants to pursue a STEAM occupation	Wants to pursue a STEM occupation
	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Can Attend Fablab	0.029	0.035	0.102	0.057	0.096	0.085	0.131**
	(0.041)	(0.059)	(0.063)	(0.059)	(0.072)	(0.066)	(0.064)
Control Mean	0.250	0.500	0.403	0.361	0.319	0.278	0.208

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
All dependent variables are binary indicators. All specifications control for baseline characteristics: the outcomes measured at baseline, school (stratum) fixed effect dummies, the number of parents who are active workers, the student's age and three other dummies indicating whether (i) student i is a male; (ii) any of the two parents of student i obtained a university degree; and (iii) student i was the first child.. Standard errors are clustered at the class level and reported in parentheses. The number of observations was 191 and 276 for females and males, respectively.

7 Conclusions

In this paper, we presented the results of a field experiment aimed at fostering interest in STEM majors and STEM careers by intervening in course activities offered to high school students for credit. We conducted an RCT in five Italian schools and randomized 42 classes (710 students, of which 573 were eventually part of the econometric analysis) to have access to creative STEM activities for credit in their schools, to learn the use of digital fabrication tools. The voluntary uptake of these activities mirrors the functioning of the current Italian schooling system, maximizing the scalability of the intervention. These courses adopted the FabLab non-mnemonic, learn-by-doing pedagogical approach, and emphasized creative thinking to build objects of actual utility. To our knowledge, this is the first study to assess an intervention based on a similar pedagogic approach to improve attitudes towards STEM.

Among the 573 students included in the analysis, we found a sizeable, statistically significant effect on the intention to pursue a university degree in STEM, with an increase of 6.1 percentage points—a 17% rise relative to the baseline. This growing orientation toward STEM fields also maps into a higher stated probability of pursuing a STEM-related professional career, with an effect of 7.4 percentage points over a baseline of 18%. These improvements were likely driven by an increase in STEM self-efficacy (a 7.3 percentage point improvement, equivalent to a 22% increase): in other words, treated students feel more confident of their ability to pursue STEM education.

Heterogeneity analyses find suggestive evidence of the existence of sex-specific pathways through which the activities operate: the technical aspects of FabLab activities seem to resonate more with male students, while females find the creative aspects more salient, although they are less likely to voluntarily enroll, potentially due to lower self-efficacy. At the same time, we find that increased self-efficacy is driven by schools where all treated students enrolled in the creative STEM courses due to a lack of alternatives.

From a policy perspective, these results suggest that the objective of increasing interest and eventual enrollment in STEM university majors among the least inclined could be achieved by making similar creative STEM activities compulsory within the existing schooling system. Indeed, while several traits of creative learning are mentioned in the latest STEM guidelines for Italian education (Ministero dell'Istruzione e del Merito, 2023), this model has only rarely been adopted in Italian high schools.

Our study faced three main limitations, which could be addressed by future research in this field. First, the relatively small size of the sample may limit the statistical power of our estimates and reduce the extent to which our findings can be generalised to broader populations. Moreover, the schools and classes participating in this study are not fully representative of the diversity of the Italian high school system, potentially affecting the external validity of the results. Third, the identified mechanisms are grounded in plausible interpretations of the observed patterns but remain largely exploratory. Future research should adopt larger samples and more diverse contexts, building on these early results that reveal the potential of a novel and underexamined type of intervention to yield broader educational gains.

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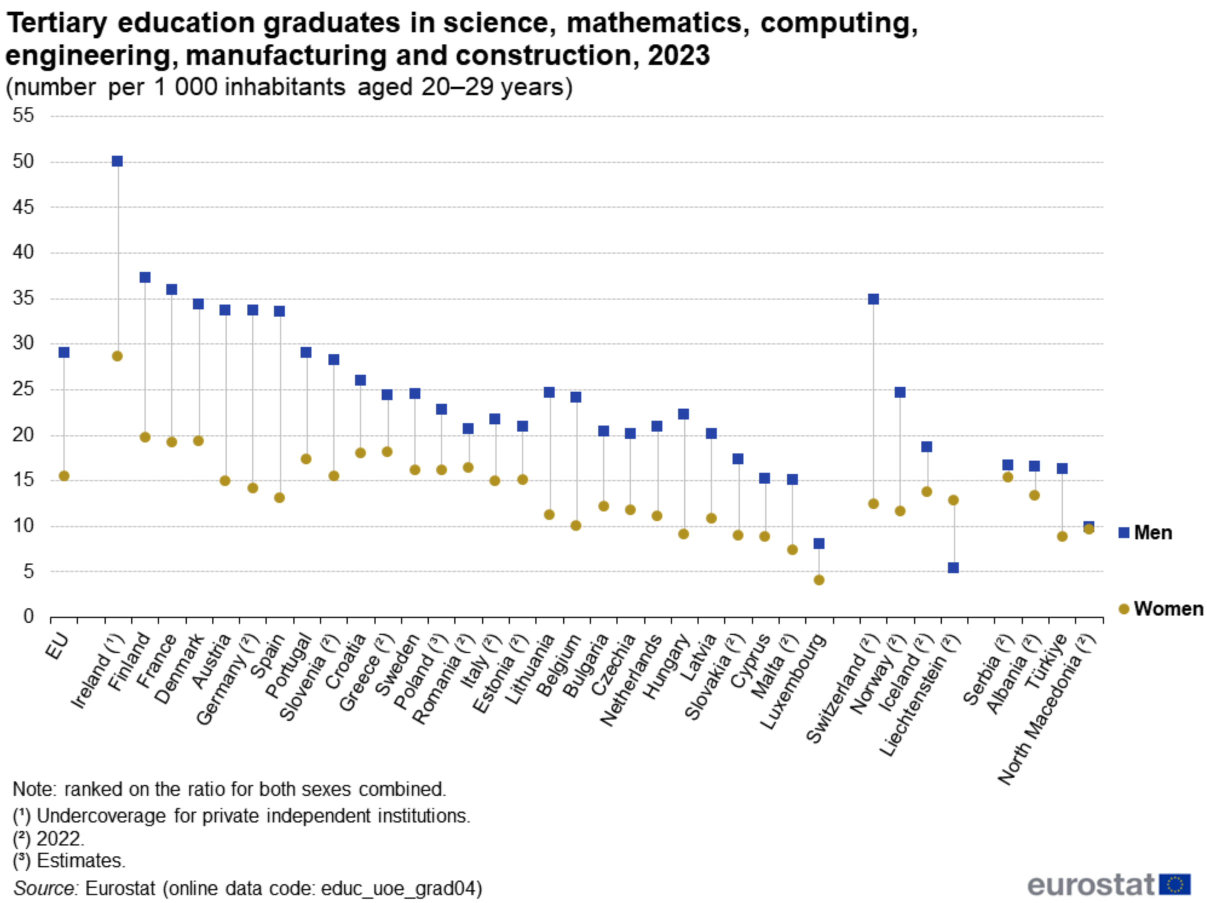
APPENDIX

A Extra Figures and Tables

Figure A.1: Shares of young STEM graduates by sex in European countries



Notes: Fields classified as STEM correspond to ISCED-13 codes 05, 06, and 07, corresponding to the classification applied to the sample under study – since code 07 includes architecture.

Figure A.2: Location of schools included in the study

Figure A.3: Compliance by Gender and School

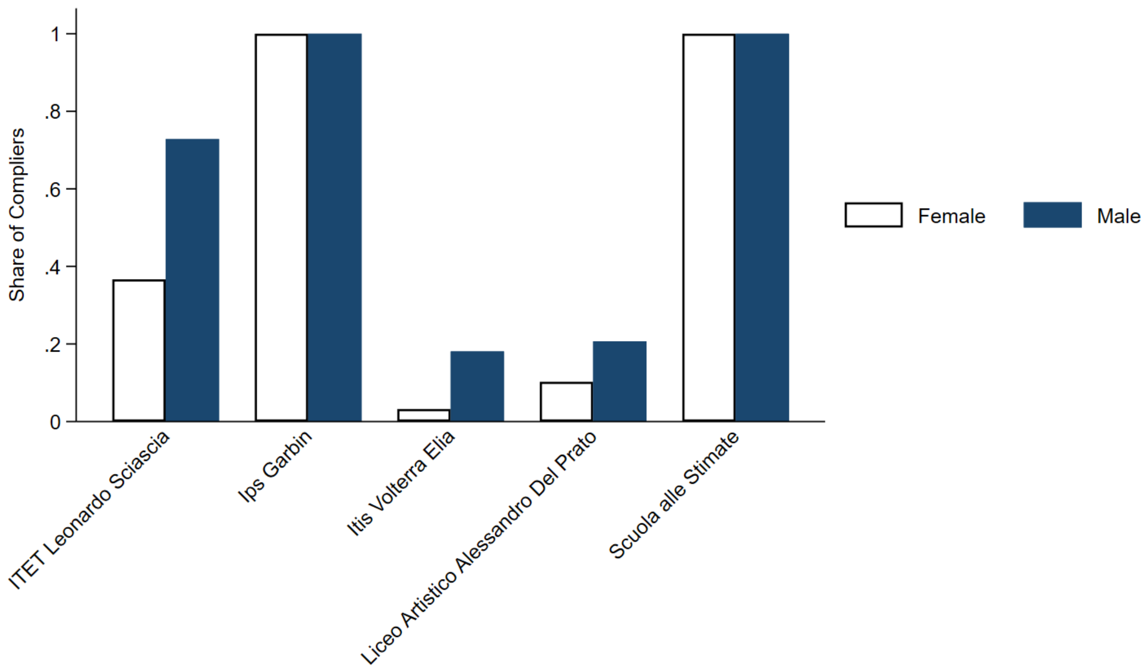


Table A.1: Intended Fields of Study at Baseline by high school major - Males

	Technical major			*Licei*		
	Agrigento	**Schio**	**Ancona**	**Verona**	**Mantua**	**Total**
Architecture	0	0	2	1	4	7
Engineering	4	14	39	9	0	66
Informatics	27	1	17	0	0	45
Science	0	1	12	5	1	19
Art	1	1	4	0	14	20
Agricultural	1	1	1	0	0	3
Economics	6	1	1	6	0	14
Sports Science	4	0	0	0	0	4
Health	3	1	3	0	1	8
Languages	2	0	0	0	0	2
Law	1	0	0	2	1	4
Nursing	4	0	0	0	0	4
Other	3	3	0	1	1	8
Psychology	4	1	1	0	1	7
Don't Know	19	33	77	1	17	147
Total	79	57	157	25	40	358

Notes: Fields of study in bold were classified as STEM. The complete list of STEM courses comprised within these macro categories includes: engineering, information technology, biology, physics, astronomy, mathematics, architecture, earth sciences, computer sciences, and chemistry.

Table A.2: Intended Macro fields of Study at Baseline by school and school major - Females

	Technical major			***Licei***		
	Agrigento	**Schio**	**Ancona**	**Verona**	**Mantua**	**Total**
Architecture	3	0	1	0	13	17
Engineering	1	2	2	3	1	9
Informatics	0	0	1	1	0	2
Science	0	0	3	2	0	5
Art	2	0	1	0	43	46
Agricultural	0	0	0	0	0	0
Economics	8	0	1	1	2	12
Sports Science	1	0	0	0	0	1
Health	1	0	7	12	0	20
Languages	11	0	0	0	2	13
Law	0	0	4	0	0	4
Nursing	2	0	0	0	0	2
Education	7	0	0	0	0	7
Humanity	2	0	0	0	0	2
Other	4	0	0	0	1	5
Psychology	6	0	2	1	6	15
Don't Know	5	0	12	2	36	55
Total	53	2	34	22	104	215

Notes: Fields of study in bold were classified as STEM. The complete list of STEM courses comprised within these macro categories includes: engineering, information technology, biology, physics, astronomy, mathematics, architecture, earth sciences, computer sciences, and chemistry.

B Deviations from the Pre-Analyis plan

This section details deviations from our pre-registered Pre-Analysis Plan, available on the American Economic Association's registry for randomized controlled trials (as AEARCTR-0011862 Dominici et al., 2025). Where relevant, these deviations have also been reported in the main text, labelling the analyses that were not pre-registered as "exploratory".

A first, necessary clarification is that the Pre-Analysis Plan also covers the outcomes assessed in a companion paper (Ballerini et al., 2024), namely grit and creativity.

The main deviations stem from the fact that we initially planned to involve up to 10 schools (strata) and 60 classes (clusters) in the experiment, for approximately double the sample size – implying also a greater variety of FabLab courses. On top of this reduction from 10 to 5 schools and from 60 to 42 classes, we experienced "inverse" attrition, as explained in the main text, meaning that while all 710 students were present at endline, we could only include 573 in the final analysis because some were absent at the baseline survey, making covariates unobservable.

As a result of sample shrinking and of significant unanticipated variation across schools in the degree of compliance (i.e., actually enrolling in FabLab courses when given the possibility), we opted for estimating an Intention-To-Treat effect by OLS rather than the pre-registered Local Average Treatment Effect by 2SLS IV, since the latter would have yielded severely underpowered, imprecise, and thus hard-to-interpret results. To relate to our initial intentions to account for imperfect compliance, we instead included an exploratory heterogeneity analysis where we re-estimate results separately for schools that exhibited perfect and imperfect compliance (Section 6.2). Similarly, these unanticipated sample characteristics prevented us from estimating heterogeneous effects by school, thereby accounting for differences in the specific project of each FabLab course, and limited our possibilities to focus more thoroughly on heterogeneity by sex.

C Removing baseline covariates

These regressions without baseline controls are presented for the sake of completeness but were not pre-registered in our Pre-Analysis Plan.

Table C.3: Possibility to attend FabLabs, university and occupational attitudes: main sample ($N = 573$) and no controls

Panel A: Main outcomes

	Wants to enroll in University (1)	Wants to enroll in STEM faculty (2)	STEM self-efficacy (3)	Interest STEM (4)	Wants to pursue a STEM occupation (5)
Can Attend Fablab	0.083	0.065	0.046	0.016	0.083**
	(0.056)	(0.047)	(0.045)	(0.047)	(0.041)
Control Mean	0.409	0.354	0.329	0.360	0.183

Panel B: STEAM outcomes (exploratory)

	Wants to enroll in STEAM faculty (1)	Wants to pursue a STEAM occupation (2)
Can Attend Fablab	0.063	0.057
	(0.051)	(0.042)
Control Mean	0.451	0.244

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
All dependent variables are binary indicators. All regressions control for school (stratum) fixed effects. The sample used comprises all students involved in the RCT ($N = 710$), regardless of whether their baseline characteristics were measured with the baseline survey or not. STEAM outcomes in Panel B are secondary outcomes and were not included in our pre-analysis plan.

Table C.4: Possibility to attend FabLabs, university and occupational attitudes: all students ($N = 710$) and no controls

Panel A: Main outcomes

	Wants to enroll in University (1)	Wants to enroll in STEM faculty (2)	STEM self-efficacy (3)	Interest STEM (4)	Wants to pursue a STEM occupation (5)
Can Attend Fablab	0.075	0.059	0.040	0.032	0.079**
	(0.051)	(0.044)	(0.043)	(0.040)	(0.039)
Control Mean	0.394	0.341	0.327	0.337	0.173

Panel B: STEAM outcomes (exploratory)

	Wants to enroll in STEAM faculty (1)	Wants to pursue a STEAM occupation (2)
Can Attend Fablab	0.052	0.059
	(0.048)	(0.040)
Control Mean	0.428	0.221

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
All dependent variables are binary indicators. All regressions only control for school (stratum) fixed effects. The sample is the same one used in the main analysis, comprising 573 students for whom we also observe baseline covariates (i.e., present on the day of the baseline survey). Standard errors are clustered at the class level and reported in parentheses. STEAM outcomes in Panel B are secondary outcomes and were not included in our pre-analysis plan.

D Surveys

In this section, we report: (i) the information sheet and consent form received and signed by the parents of all students in the sample; (ii) the English translation of the surveys administered to the students, originally in Italian. Survey section names are reported for the sake of readability, but were not visible to the students. In these documents, we nominate the European University Institute and the University of Florence, which were the authors' affiliations at the time of the RCT implementation.

D.1 Information and consent form for parents

General Information on Data Processing Pursuant to current legislation on the protection of personal data, we inform you that the personal data you provide will be processed lawfully and fairly for purposes related and necessary to the scientific research *"Digital skills, university choice and non-cognitive skills: a Randomized Trial"* of the Fabschool project. The research aims to assess the impact of courses aimed at enhancing digital skills on students' interest in technology, creativity, and professional aspirations.

To achieve this goal, questionnaires or other qualitative research activities will be carried out for scientific research purposes related to satisfaction or self-perception within one's environment, with particular attention to non-formal skills and to any educational/professional opportunities that may have arisen following participation in the courses.

With regard to the scientific research, the data will be processed exclusively by:

- European University Institute (EUI)
- University of Florence

The data controller will be Dr. Martina Francesca Ferracane, who will collaborate with a team of 5 researchers from the European University Institute and the University of Florence.

1. Legal basis — The legal basis for the processing of data is the informed and explicit consent of the data subject, as defined by Articles 5 and 8 of the EUI Data Protection Policy (President's Decision 10/2019), which is based on the principles of the European Data Protection Regulation. In the case of underage participants, consent must be given by those holding parental responsibility. Consent is not mandatory, and the student will not be excluded from the project if they are not interested in participating in the scientific research. Consent may be withdrawn at any time and will remain valid for the entire duration of the activities of the Fabschool project.

The personal data processed are:

- Personal details of the participant and their parents
- Contact details (email/phone) of the participant or their parents (if the participant is underage)
- Data relating to the image and voice of participants obtained through online questionnaires, audio interviews, photos, and videos

- Data relating to the school attended, class and year of enrollment, as well as academic performance

The only sensitive data processed will be the student's gender.

Data will be collected via online questionnaires using the Qualtrics platform and interviews recorded using Microsoft Word. All data are stored on a cloud platform that complies with data protection regulations. Data will be accessible only to researchers directly involved in the scientific research and will not be shared with third parties.

The processing of photos and videos may take place only with the participant's consent, or the consent of a parent (in the case of an underage participant). Consent to photos and videos is voluntary, and refusal will not affect participation in project activities. For a project like Fabschool, an essential aspect is sharing results and best practices through the production of photos and videos to be shared on commonly used channels. If you choose to give consent, you will also contribute to the dissemination of the project among new generations and the local community.

The data collected during the qualitative research and scientific activities of the Fabschool project will be disseminated exclusively in aggregated and anonymous form. This means that the results of an individual participant will never be disclosed in a way that would allow identification. If authorization is requested for the sharing of information that could identify a participant, a separate free and specific consent request will be made.

2. Data retention — The data relating to the scientific research will be kept for a maximum of 3 years after the conclusion and publication of the research, unless different legal or contractual obligations require longer retention. The reason for retaining the data for 3 years is to allow verification of whether the student is interested in participating in further studies to assess the medium- to long-term impact of the project. The data will always be pseudonymized.

3. Rights of the data subject — With regard to your personal data, you have the right to exercise all the rights provided for by Article 16 of the EUI Data Protection Policy. This policy provides that the data subject:

- (a) Is informed if, how, by whom, and for what purpose their data are processed;
- (b) May request the rectification of data if the information is inaccurate or incomplete;
- (c) May request the deletion of data if the processing is unlawful or no longer necessary;
- (d) May block further processing when the conditions under points b) and c) are met.

To exercise your rights, you may at any time contact the Data Controller at the European University Institute at: `martina.ferracane@eui.eu`

4. Requests and complaints — Any requests or complaints may be sent to the European University Institute via email to `martina.ferracane@eui.eu`, copying `data_protection_offer@eui.eu`.

Data Collection and Consent to Processing Having read and understood the above information in all its parts, the adult participant, or the parents in the case of a minor participant:

☐ Authorize the processing of data in the manner indicated in this notice and also authorize requesting from the school the data indicated in point 1.d.
☐ Do not authorize the processing of data in the manner indicated in this notice.

Date: ______________________________
Signature (adult participant or parents): ____

In signing below, in the capacity of having parental responsibility for the minor participant, the undersigned:

- Declares that, at the time of signing, they have parental responsibility for the minor;
- Declares that they sign with the consent of the other parent or have the right to exercise responsibility exclusively, or otherwise have a legally valid title (e.g., a court order) allowing them to act without the other parent's consent;
- Assumes full responsibility for the statements made, releasing the project partners from any liability in the event of false or incomplete declarations or if circumstances arise that are not communicated.

The consent concerns the following participant:
Name: ____
Surname: ____
Date of birth: ____
Home address: ____

Telephone number: ____

E-mail: ____

D.2 Baseline Survey

Hi!

You will have about 30 minutes to complete this questionnaire, though it might take less time. The purpose of the questionnaire is to collect data for a scientific research project of the European University Institute and the University of Florence. We aim to understand whether certain PCTO activities help to develop some personal characteristics.

Your individual data will never be disclosed to anyone (including your school) or published.

If you wish to go back and change an answer, you can do so using the buttons at the bottom of the page.

Studies The next questions are about your school experience and your ambitions for the future.

1. What is your favorite subject? You can indicate up to 2 subjects.
2. Which subjects do you like the least, or find most difficult? You can indicate up to 2 subjects.
   - Italian
   - History
   - Philosophy
   - English or other foreign language
   - Mathematics
   - Chemistry
   - Physics
   - Biology
   - Physical Education

- Other (specify)

3. How much do you like science subjects, for example computer science, biology, chemistry, and similar subjects?

    - I don't like them at all
    - I tend not to like them
    - I am indifferent
    - I tend to like them
    - I like them
    - I like them very much

4. Do you already know what you would like to do when you grow up? If yes, what? (you can give more than one answer)

    - Yes
    - No
    - I am not sure yet

5. Would you like to go to university?

    - Yes
    - No
    - I am not sure yet

6. If you are considering going to university, which faculty do you think you will enroll in? (you can give more than one answer)

7. If you went to university, would you feel able to follow a STEM course? STEM subjects are those related to engineering, mathematics, statistics, computer science, biology, chemistry, physics, and similar.

    - Yes
    - No
    - I am not sure

8. At university, would you be interested in taking STEM courses? (same definition as above)

    - Yes

- No
- I am not sure

9. Why would you be or not be interested in taking STEM courses? (open answer)

Creativity

1. Do you like doing any of the following activities? You can indicate more than one.
    - Composing music
    - Playing an instrument or singing
    - Taking photographs
    - Writing and/or making videos
    - Painting or drawing
    - Writing prose or poetry
    - Making sculptures with various materials or ceramic pieces
    - Building objects
    - Other creative activities (specify)
    - None of the above
2. Below you will find several statements that people use to describe themselves. Please indicate the extent to which each statement describes you. There are no right or wrong answers.
    - I think I am a creative person.
    - My creativity is important in defining who I am.
    - I know I can solve even complex problems efficiently.
    - I trust my creative abilities.
    - My imagination and ingenuity set me apart from my friends.
    - I have repeatedly demonstrated that I can face difficult situations.
    - Being a creative person is important to me.
    - I am confident I can tackle problems that require creative thinking.
    - I am good at finding original solutions to problems.
    - Creativity is an important part of who I am.

- Ingenuity is an important characteristic for me.

Response scale:

- Definitely not
- More no than yes
- Neither yes nor no
- More yes than no
- Definitely yes

3. In the next question, we will ask you to think of as many possible uses as you can for a common object. Example: a brick can be used as a step, a paperweight, a doorstop. If you drill a hole in the middle, it can be used as a flag base. You will have 2 minutes to list all possible uses you can think of.

   - Object: a plastic bottle How could you use a plastic bottle? List all uses you can think of in 2 minutes, separated by commas. (open answer)

4. The next question is similar but presents a situation that requires creative thinking, and you must give a single solution. You have 5 minutes. Imagine that in the future bicycles will no longer need pedals. Think of an original way to reuse a bicycle pedal. The idea should be original in the sense that not many students would think of it. (open answer)

Grit For each statement, indicate how accurately it describes you, compared to most people.

- New ideas and projects often distract me from those I am already working on.
- Obstacles do not discourage me. I do not give up easily.
- I often set a goal but then choose to pursue another.
- I am a hard worker.
- I find it difficult to maintain focus on projects that take more than a few months to complete.
- I finish everything I start.
- My interests change from year to year.
- I am diligent. I never give up.

- I have been obsessed with an idea or project for a short period and then lost interest.
- I have faced and overcome obstacles to win an important challenge.

Response scale:

- Does not describe me at all
- Describes me very little
- Describes me partially
- Describes me fairly well
- This is exactly me

Math How much do you agree with the following statements?

- It is worth making an effort in mathematics because it will help me improve my job prospects.
- Mathematics is important to me because it is necessary for what I want to study later.
- I willingly do mathematics because I enjoy it.
- If I try hard enough, I can get good grades in mathematics.
- I do badly in mathematics regardless of how much I study.
- How well I do in mathematics depends only on me.
- During mathematics lessons, I pay attention.
- I study very hard for mathematics tests.

Response scale:

- Strongly disagree
- Disagree
- Agree
- Strongly agree

Education 2

1. What is the name of your school? (open answer)
2. What is your class/section? (e.g., 3B) (open answer)
3. Approximately, what is your grade point average? (0 to 10 scale)
4. If you have already started PCTO (school-to-work programs), how many hours have you already completed? (number or "I don't know")
5. How many hours of PCTO do you still need to complete? (number or "I don't know")
6. Have you already done PCTO or other extracurricular courses? If yes, briefly describe them.
7. Do you know about FabLabs?
   - Yes
   - No
8. Have you ever attended FabLab courses?
   - Yes, many times
   - Only a few times
   - Never / I don't know them
9. Have you ever participated in CoderDojo activities or similar activities?

Demographics

1. What is your gender identity?
   - Male
   - Female
   - Non-binary
2. What is your biological sex?
   - Male
   - Female

- Other

3. How old are you? (two-digit number, e.g., 19)
4. Are you an only child?
   - Yes
   - No
5. Are you the firstborn?
6. Does any member of your household run a business, store, or professional office?
7. Which of the following best describes your parents?
   - Both work or are retired
   - One parent works or is retired
   - Neither parent works/has ever worked
8. To your knowledge, have your parents (one or both) attended university?
   - Yes, both
   - Yes, only my father
   - Yes, only my mother
   - No, neither
   - I am not sure
9. If your father or mother attended university, did they attend any of the following faculties? (multiple answers possible)
   - Engineering
   - Biology
   - Chemistry
   - Physics
   - Computer Science
   - Mathematics
   - Statistics
   - Economics

- None of the above (specify)
- I don't know

10. Name and surname (for matching responses with end-of-year survey; will be removed before analysis)

Final Do you have any questions, clarifications, or comments about this questionnaire? (open answer)

D.3 Endline Survey

Hi!

You will have about 30 minutes to complete this questionnaire, though it might take less time. The purpose of the questionnaire is to collect data for a scientific research project of the European University Institute and the University of Florence. We aim to understand whether certain PCTO activities help to develop some personal characteristics.

Your individual data will never be disclosed to anyone (including your school) or published.

If you wish to go back and change an answer, you can do so using the buttons at the bottom of the page.

Creativity

1. How creative do you feel? Scale: 0 = Not at all, 10 = Very much
2. Do you like doing any of the following activities? You can select more than one.
   - Composing music
   - Playing an instrument or singing
   - Taking photographs
   - Writing and/or making videos
   - Painting or drawing
   - Writing prose or poetry
   - Making sculptures with various materials or ceramic pieces

- Building objects
- Other creative activities (specify)
- None of the above

3. Below you will find several statements that people use to describe themselves. Please indicate the extent to which each statement describes you. There are no right or wrong answers.

   - I think I am a creative person.
   - My creativity is important in defining who I am.
   - I know I can solve even complex problems efficiently.
   - I trust my creative abilities.
   - My imagination and ingenuity set me apart from my friends.
   - I have repeatedly demonstrated that I can face difficult situations.
   - Being a creative person is important to me.
   - I am confident I can tackle problems that require creative thinking.
   - I am good at finding original solutions to problems.
   - Creativity is an important part of who I am.
   - Ingenuity is an important characteristic for me.

   Response scale:

   - Definitely not
   - More no than yes
   - Neither yes nor no
   - More yes than no
   - Definitely yes

4. In the next question, we will ask you to think of as many possible uses as you can for a common object. Example: a brick can be used as a step, a paperweight, a doorstop. If you drill a hole in the middle, it can be used as a flag base. You will have 2 minutes to list all possible uses you can think of.

   - Object: a can How could you use a can? List all uses you can think of in 2 minutes, separated by commas. (open answer)

5. The next question is similar but presents a situation that requires creative thinking, and you must give a single solution. You have 5 minutes. Imagine the bicycles of the future. How would you improve them? The idea should be original in the sense that not many students would think of it. (open answer)

Grit For each statement, indicate how accurately it describes you, compared to most people.

- New ideas and projects often distract me from those I am already working on.
- Obstacles do not discourage me. I do not give up easily.
- I often set a goal but then choose to pursue another.
- I am a hard worker.
- I find it difficult to maintain focus on projects that take more than a few months to complete.
- I finish everything I start.
- My interests change from year to year.
- I am diligent. I never give up.
- I have been obsessed with an idea or project for a short period and then lost interest.
- I have faced and overcome obstacles to win an important challenge.

Response scale:

- Does not describe me at all
- Describes me very little
- Describes me partially
- Describes me fairly well
- This is exactly me

Studies

1. What is your favorite subject? You can indicate up to 2 subjects.
2. Which subjects do you like the least, or find most difficult? You can indicate up to 2 subjects.
    - Italian
    - History
    - Philosophy
    - English or other foreign language
    - Mathematics
    - Natural and physical sciences (chemistry, physics, biology)
    - Physical Education
    - Arts / Art subjects
    - Economics
    - Laboratory activities
    - Computer Science
    - Latin / Greek
    - Law
    - Mechanics and applied sciences and technologies
    - Other (specify)
3. How much do you like scientific and technological subjects, for example computer science, biology, chemistry, technology, and similar?
    - I don't like them at all
    - I tend not to like them
    - I am indifferent
    - I tend to like them
    - I like them
    - I like them very much
4. Do you have ideas about the job you would like to do when you grow up?

5. If yes, what job do you imagine?
6. Even if you do not yet know what job you will do, can you share some ideas?
7. Imagine yourself as an adult. Realistically, what job do you think you will do?
8. If the job you would like to do is different from the one you realistically think you will do, why?
   - I don't think I would have the right skills
   - I don't think I am suited for it
   - It's hard to find this kind of job in Italy
   - It requires training that is too expensive
   - The job I would like is the same as the one I realistically think I will do
   - Other (specify)
9. Would you like to go to university?
   - Yes
   - No
   - I am not sure yet
10. If you are considering going to university, which faculty do you think you will enroll in? (you can give more than one answer)
    - Architecture
    - Fine Arts Academy
    - Economics
    - Law
    - Engineering
    - Computer Science and Technologies
    - Nursing and health professions
    - Classical and Modern Literature
    - Languages
    - Medicine
    - Psychology

- Education Sciences
- Sports Sciences
- Natural, physical and mathematical sciences
- Communication Sciences
- Political Science
- ITS (post-secondary technical specialization schools, no degree awarded)
- Other

11. At university, would you be interested in taking STEM courses? STEM subjects are those related to engineering, mathematics, statistics, computer science, biology, chemistry, physics, and similar.
    - Yes
    - No
    - I am not sure
12. Why would you be or not be interested in taking STEM courses? (open answer)
13. If you went to university, would you feel able to follow a STEM course? (same definition as above)
    - Yes
    - No
    - I am not sure

Math How much do you agree with the following statements?

- It is worth making an effort in mathematics because it will help me improve my job prospects.
- Mathematics is important to me because it is necessary for what I want to study later.
- I willingly do mathematics because I enjoy it.
- If I try hard enough, I can get good grades in mathematics.
- I do badly in mathematics regardless of how much I study.
- How well I do in mathematics depends only on me.

- During mathematics lessons, I pay attention.
- I study very hard for mathematics tests.

Response scale:

- Strongly disagree
- Disagree
- Agree
- Strongly agree

Education 2

1. In which city is your school located? (list of options given in original)
2. What is the name of your school? (list of options given in original)
3. What is your class/section? (list of options given in original)
4. Approximately, what is your grade point average? (0 to 10 scale)
5. Have you already done PCTO (school-to-work programs) or other extracurricular courses? If yes, briefly describe them.
6. Do you know about FabLabs?
    - Yes
    - No
7. Have you ever attended FabLab courses?
    - Yes, many times
    - Only a few times
    - Never / I don't know them
8. Have you ever participated in CoderDojo activities or similar activities?

Demographics

1. What is your gender identity?
    - Male
    - Female
    - Non-binary
2. What is your biological sex?
    - Male
    - Female
    - Other
3. How old are you? (two-digit number, e.g., 19)
4. Are you an only child?
    - Yes
    - No
5. Are you the firstborn?
6. Does any member of your household run a business, store, or professional office?
7. Which of the following best describes your parents?
    - Both work or are retired
    - One parent works or is retired
    - Neither parent works/has ever worked
8. To your knowledge, have your parents (one or both) attended university?
    - Yes, both
    - Yes, only my father
    - Yes, only my mother
    - No, neither
    - I am not sure
9. If your father or mother attended university, did they attend any of the following faculties? (multiple answers possible)

- Engineering
- Biology
- Chemistry
- Physics
- Computer Science
- Mathematics
- Statistics
- Economics
- None of the above (specify)
- I don't know

10. Name and surname (for matching responses with baseline survey; will be removed before analysis)

Final Do you have any questions, clarifications, or comments about this questionnaire? (open answer)

E Multiple Hypothesis Testing

As detailed in Section 4.2 of the main text, we classified our primary outcomes into three families: (i) University choice (two measures: willingness to attend university and willingness to enroll in a STEM faculty), (ii) Attitudes (two measures: self-reported interest and ability in STEM), and (iii) Occupation (one measure: willingness to pursue a STEM occupation).

These outcomes are all positively correlated both across and within families: a Bonferroni correction is therefore too conservative, as it assumes independence between outcomes. Nevertheless, of our three significant estimates, both the result for self-reported STEM ability (T stat = 2.21) and the result for the willingness to pursue a STEM occupation (T stat = 2.24) are robust to a Bonferroni correction for three families of outcomes at the 10% significance level (critical value 2.12).

However, to account for multiple hypothesis testing while acknowledging the positive dependence of outcomes, we implemented a hierarchical false discovery rate (FDR) control following the Benjamini and Bogomolov (2014) procedure. This is a less conservative two-step approach, relative to Bonferroni, that controls the expected proportion of false discoveries while accounting for the correlation structure both across and within outcome families. As a first step, for each family, we first computed a *class-level* p-value using the Simes (1986) method, which orders the m p-values within a family as $p_{(1)} \leq \cdots \leq p_{(m)}$ and defines the Simes p-value as

$$p_{\text{Simes}} = \min_{1 \leq k \leq m} \left\{ \frac{m}{k} \, p_{(k)} \right\}.$$

This procedure controls the family-wise error rate under independence and certain forms of positive dependence, making it appropriate for positively correlated outcomes within a family.

We then applied the Benjamini–Hochberg (BH) procedure to the three class-level p-values to control the FDR across families. The BH procedure consists of: (1) sorting the M p-values in ascending order, $p_{(1)} \leq \cdots \leq p_{(M)}$; (2) finding the largest rank k such that

$$p_{(k)} \leq \frac{k}{M} \, q,$$

where q is the desired FDR level; and (3) rejecting the null hypotheses for all p-values with rank $i \leq k$. At $q = 0.10$ and $M = 3$, the BH thresholds are 0.0333, 0.0667, and 0.10 for ranks 1, 2, and 3, respectively. Since all three Simes p-values (0.025, 0.054, 0.084) are below their respective thresholds, all three families were selected for within-family testing.

For the subset of families selected at the class level (here, all three), we applied the BH procedure again within each family to the original outcome-level p-values. Following Benjamini and Bogomolov (2014), the within-family BH was applied at a level $(R/M) \cdot q$, where R is the number of families selected in the first step and M is the total number of families. With $R = 3$ and $M = 3$, this yields the same target level of $q = 0.10$ within each family. This second stage identified one significant outcome in each family: *Wants to enroll in STEM faculty* (*University choice*), *Self-reported STEM ability* (*Attitudes*), and *Wants to pursue STEM occupation* (*Occupation*).

Table E.5: Hierarchical FDR adjustment by outcome family

Family	Raw p-values	Family Simes' p-value	Significant outcome at FDR 10%
University choice	0.166, 0.042	0.084	Wants to enroll in STEM faculty
Attitudes	0.375, 0.027	0.054	Self-reported STEM ability
Occupation	0.025	0.025	Wants to pursue STEM occupation

Notes: The raw p-values refer to our main results displayed in Table 4, in the main text, where no multiple hypothesis correction was applied. Simes' p-values are computed within each family. "Significant" indicates rejection of the null (i.e., coefficient equal to zero) after class-level and within-family Benjamini–Hochberg adjustments, controlling the false discovery rate (FDR) at 10%.