# Online remedial courses for missing mathematics credits in scientific degree programmes: are they effective?

**Ottavio G. Rizzo**

Dipartimento di Matematica "Federigo Enriques", Università degli Studi di Milano

E-mail: Ottavio.Rizzo@unimi.it

**Abstract.** Analizziamo la correlazione fra la frequenza al corso di recupero online 2018 per 310 studenti con debito del corso di laurea in Scienze Naturali dell'Università di Milano e il loro successo formativo, definito come passare l'esame di Istituzioni di Matematiche nel minor tempo possibile.

## 1  The context

The 3-year bachelor programme in Natural Sciences at the University of Milan removed limited admission in the academic year 2018/2019: students since have only been required to sit a non-selective test for assessing their preparation (TOLC-C: see §3.1 in Rattini, 2016). A score of 10 points or less out of 20 in the Mathematics section of TOLC-C carries the assignment of *Additional Learning Obligations* (OFA: Obblighi Formativi Aggiuntivi). OFA prevent students to sit second year exams and they can be satisfied either by attending and passing an online remedial course or by passing the Mathematics & Statistics course; the remedial exam is offered only in December and can be taken just once; Maths & Stats is a two terms course (12 ECTS).

As a result of unlimited admission, enrolment in the degree programme has been exploding (cfr. Figure 1); although the percentage of students with OFA has historically been high in the programme, now they represent the majority of students with OFA in the entire faculty of Science and the near totality of students with a *negative* [sic!] score in TOLC.

### 1.1  The remedial course

The remedial course is a commercial one, sold by a publishing house and paid for by the Piano Nazionale Lauree Scientifiche, a government project to increase the success in scientific studies.

It consists in weekly sets of exercises, with progression control and it is supplemented by a 2-hours-per-week in presence tutoring in smallish groups. Using Stanford's (2000) classification (Figure 2), we say that the course is in the lower left *Green Zone* (aka *Underappreciated Workhorses*).

Online cheating is not a significative issue since the pass/fail grade is awarded after a written examination, and only progression control is applied; thus no need for data securization (Kausar & al., 2020) was felt.

The course content is grade 9-10 Arithmetic, Algebra and Functions — very similar to what is asked for by the grade 9–10 National Curriculum (*Indicazioni nazionali riguardanti gli obiettivi specifici di apprendimento per i licei*, 2017) — with some logarithm and exponentiation thrown in. No calculus — it being the main subject of the Mathematics freshman course — and no trigonometry.

The exercises offer a feedback which is granular albeit seriously suffering of symptoms of Brousseau (2002) *didactic contract* (cfr. Figure 1): the proposed exercise asks to write the result as a ratio of two integers but

does not actually accept a ratio of two integers: the pop-up says that the result is correct but not in the correct format since the two numbers I gave are not relatively prime to each other.
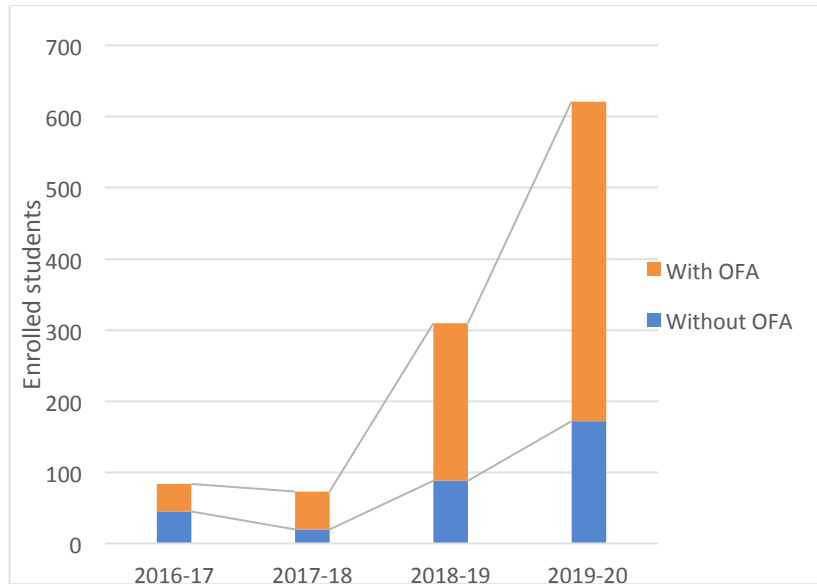


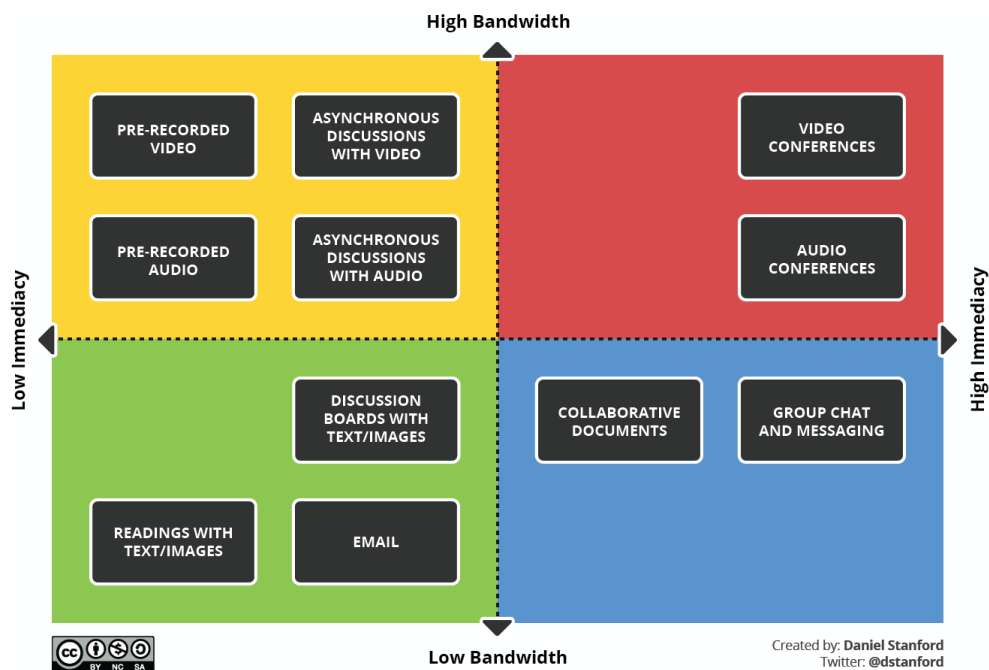**Figure 1:** Enrollment in the Natural Science BA programme



**Figure 2**: Stanford's Bandwith Immediacy Matrix

### 1.2    *Students' difficulties*

A perfunctory analysis of students' productions during written exams shows the occurrence of most difficulties related to the transition from secondary to tertiary mathematics (Biehler, 2019), aggravated by a poor knowledge of basic secondary mathematics, by a poor confidence in mathematics and by an apparent lack of links between calculus and professional practice: while genetics and bio-informatics have pushed the per-

ceived importance of mathematics in the biology curriculum (Durán & Marshall, 2019) the same does not appear to hold for the students in question.
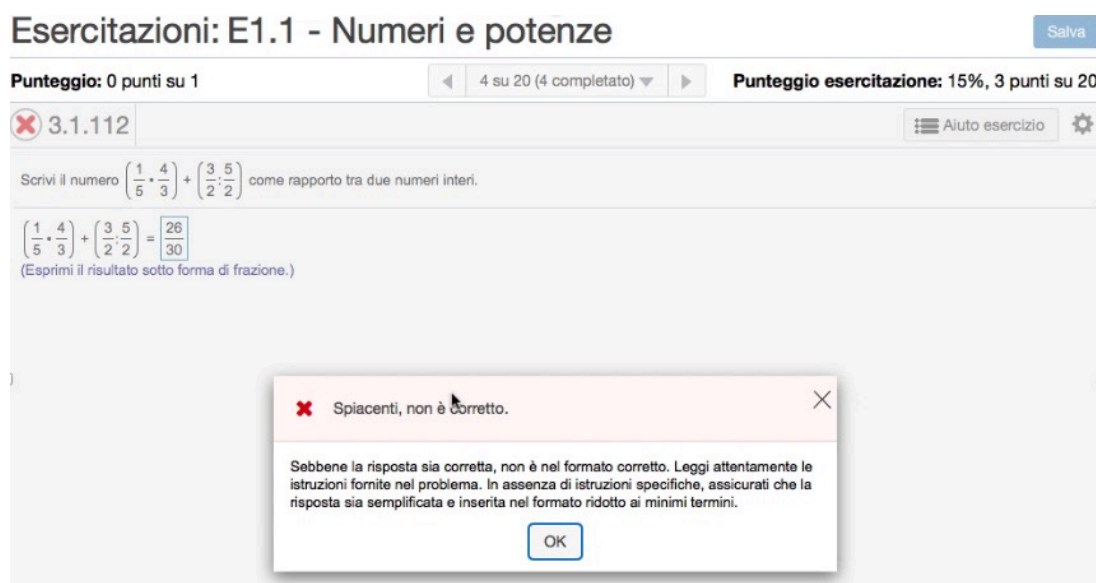


**Figure 1.** A screenshot from the online course

Following De Guzmán & al. (1998), we notice in particular the following:

- Epistemological and cognitive difficulties: the level of conceptual understanding required is significantly higher: "I have no idea where to start" is a way too common answer to any slightly off standard question, even when they show the ability to perform the required manipulations which are at (or often lower than) the level required in high school.
- Sociological difficulties: at more than 300 students, the size group of the class was very large; even when the class was split in half during recitations; transportation time appears to be a significant issue, too.

*Students' reaction towards the remedial course*

Casual conversations with students at the end of class or during office hours showed that finding the time for taking seriously the remedial course was a significant issue and so we claim this should be considered as an additional difficulty. An online questionnaire was administered the last week of classes in January 2020: only 98 students out of 200 still attending the course and 621 officially enrolled answered. Of these, 74 had to attend the remedial course: half spent on average less than 2 h/week on the remedial course, only 10% spent more than 6 h/week. Indeed, 45% of students spent more than 1 h to get to class each morning, with only 17% spending less than 30'.

Proper interviews could not be conducted due to the COVID-19 pandemic: these would have been helpful in exploring how advantages and disadvantages of at-distance learning affected the remedial course and how, if at all, the online material was supported by the in presence remedial classes.

## 2   The theoretical framework

The theoretical lens used for the evaluation and eventual future (re)design of the remedial course is that of activity theory as presented by Engelström (1999) and specialized to online activities following Barab (2004): in particular we view the collaborative space as a *socio technical interaction network* (Kling & al., 2003).

The way people communicate alter the communication: be it amplifiers in a lecture hall, recorded (asynchronous) or live (synchronous) lectures, on-line forums or interactive web-sites, the *technique* will shape what is communicated: a different *mediating artifact* will beget a different *community* which will produce a different *outcome*. The social and the technical aspects should not, hence, be viewed as separate entities but as an intertwined interaction network (STIN) with its core interactive groups, incentive structure, exluded actors, undesired interactions, resource flows.
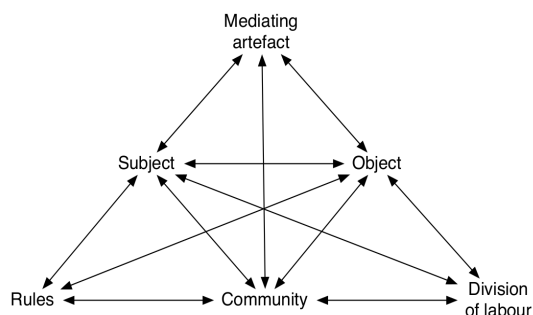


**Figura 4.** The model of activity theory

## 3  What does effective mean?

In order to asses effectiveness, a proper definition of success had to be put forward. There is no consensus on the purpose of higher education in the 21st century, student expectations in particular being far from the self-defined purpose of higher education institutions (Chan, 2016); nevertheless, the literature agrees that graduation is a positive endeavour: but graduation is begat by passing exams; passing exams is begat by taking exams; taking second year exams is begat by not having OFA; not having OFA is begat by getting a good score in the admission exam, by passing the OFA test or by passing the Maths & Stats course.

Passing the Maths & Stats course is indeed a requirement for graduation, and a tough one for the students of the programme degree. Moreover, students are allowed to sit the Statistics exam only if they passed the first term Mathematics exam. We therefore propose the following definition of success: passing the Mathematics exam during the academic year and spending as less time as possible in the effort. For the 2018 class, this means passing the exam either in February, March, June, July, September, November 2019 or January 2020. Students were allowed to sit every exam to their liking.

## 4  The data

All data refers to the 2018 class. Due to the COVID-19 pandemic there was not sufficient data from the 2019 class before lock-down started to infer any result and the format of the following exams had to be changed (in particular they moved online) so that comparisons would be difficult.

Out of 310 students that enrolled as freshmen, 222 had OFA; only 206 freshmen sat on some of the aforementioned Math exam. Since the current enrolment at the second year is 192 students, this is consistent with the hypothesis that about a hundred students either dropped out or transferred to another programme degree.

| TOLC result | Never passed the exam | Passed after 1 try | Passed after 2 tries | Passed after 3 tries | Passed after 4 tries |
|---|---|---|---|---|---|
| -2–0 | 13 | | | | |
| 1–3 | 24 | 2 | | | 2 |
| 4–6 | 29 | 6 | 6 | 1 | 1 |
| 7–9 | 19 | 15 | 5 | 2 | 1 |
| 10–12 | 12 | 26 | 5 | 2 | |
| 13–15 | 4 | 10 | 3 | | |
| 16–18 | *1* | *13* | *1* | | |
| 19–21 | | 3 | | | |

**Table 1.** Number of times students sat the exam wrt TOLC score range

### 4.1    TOLC Vs. success

In Table 1 and Figure 5, we tabulate the number of times a student had to sit the exam before getting a passing grade with respect to the TOLC entrance exam score; *NO* means that the student had sat at least once but never passed the exam.
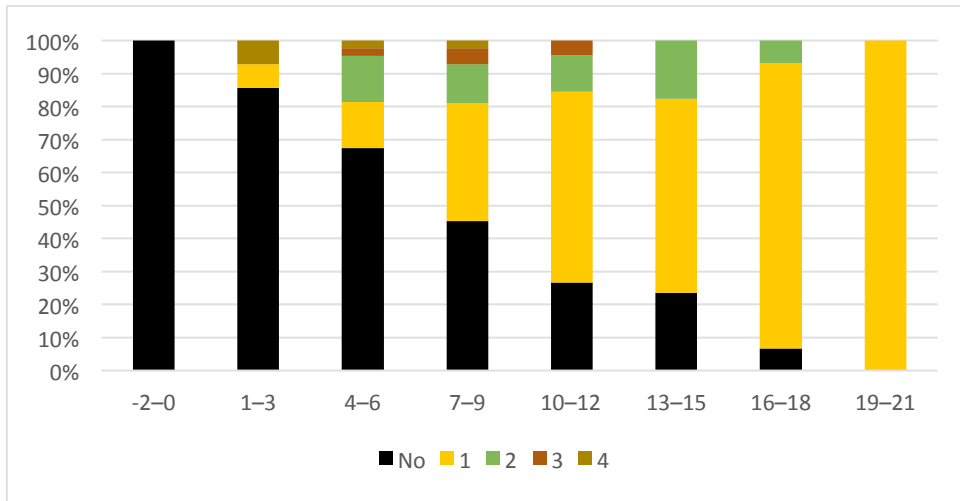


**Figure 5.** Number of times students sat the exam wrt TOLC score

The first remark is that a score $\geq 10$ is actually a good predictor of success: this justifies the choice of the threshold. The second remark is that a score $\leq 3$, resp. $\geq 16$, is a good predictor of failure, resp., success. A third remark is that students either pass the exam first time they sit it, or they do not pass it: this shows that offering a high number of exams during the year is of little use to students.

Finally, if we tabulate the percentage of outcome with respect to TOLC score we get a coefficient of determination $R^2 = 0,975$ between TOLC score and chance of never passing the exam. We only get $R^2 = 0,75$ if we compare TOLC score with chance of passing the exam first time.
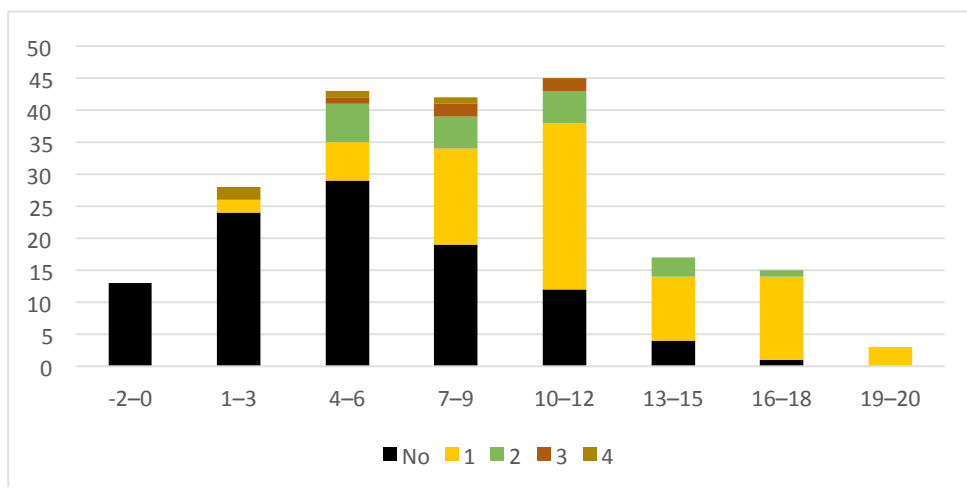


**Figure 6.** Expected number of times before passing wrt TOLC score

### 4.2    OFA test Vs. success

We consider now the relationship between passing the OFA test and success, as a first measure of the effectiveness of the remedial course.

Firs we consider those students that actually passed the OFA test (Figure 7): none of them had a negative TOLC score; out of the four that had a score in the 1–3 range, 2 have not passed the exam, 1 passed it the first time (s)he sat it and 1 after sitting it four times; out of the 17 that had a score in 4–6 range, 6 have not passed, 5 after 1 try, 5 after 2 tries, 1 after trying it 4 times; out of the 19 students in the 7–9 range, 6 have not passed, 8 after 1 try, 4 after 2 tries, 1 after 3 tries. Similar data was used to draw Figures 7–9.

The comparison between Figure 7 and Figure 8shows the existence of a very strong correlation between passing the test and passing the exam. In particular, almost every student that passes the exam second time had beforehand passed the OFA test.

We also notice that only students that barely did not qualify at the entrance test (score 7–9) have actually some chance of passing the exam, and if they did, they would do so first time.

In Figure 9 and Figure 10 we split students of Figure 8 between those that did not pass the OFA test and those that could not take it because they did not respect the weekly exercise schedule: there is not significant difference between the two sets with respect to failure, so we can deduce that mere attendance of the remedial course was of no help.
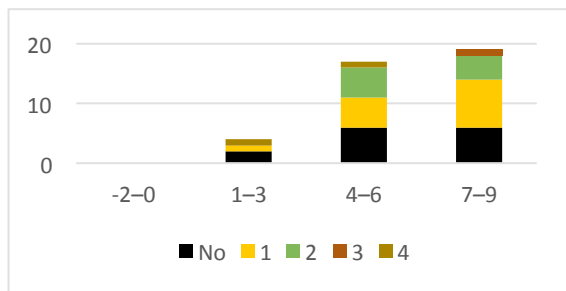


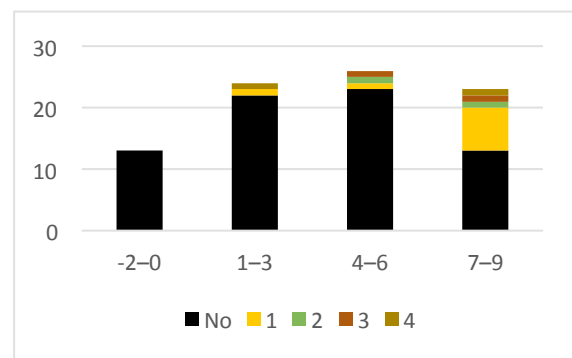**Figure 7.** Students that passed the OFA test



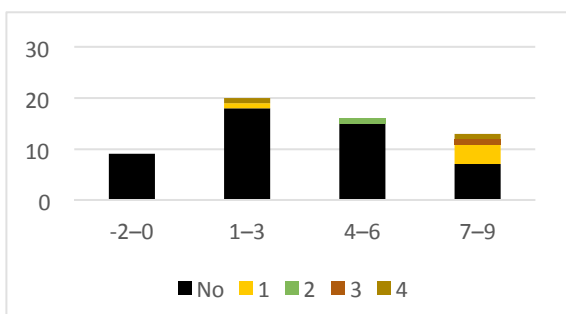**Figure 8.** Students who did not pass or did not

qualify for test



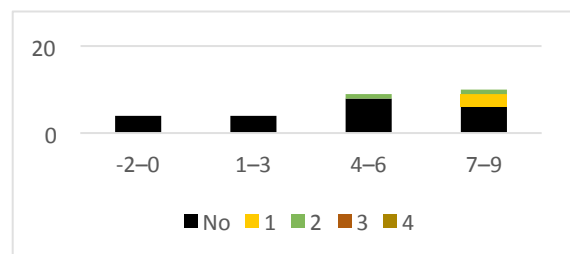**Figure 9.** Students who did not pass the OFA

test



**Figure 2.** Students who did not qualify for the

test

### 4.3 Is the remedial course effective?

Correlation is no causation! If we apply the maxim to our case, we can envision at least three different scenarios:

1. The course is effective, so students that take it seriously gain a solid base on which they can successfully build the knowledge required to pass the Math exam.
2. Some students that had a not so good experience with high school mathematics choose to put down to work, so they pass the OFA test and later the exam, albeit with some difficulty.
3. Students that had the time and self-organization to study in November and December for the OFA test, had the time and self-organization to study and pass the Math exam.

Actual effectiveness of the remedial course could be surmised only from the first scenario, so care should be used. The apparent ineffectiveness of just handing in the weekly assignments rises a bell, too. The results of the questionnaire cited in §1.2 hint strongly to the third scenario.

### 4.4 What is missing?

The scant evidence we were able to gather with informal talks with students suggests the course as implemented could not be interpreted as an Inquiry Learning Forum (ILF, cfr. Barab, 2004): since this would be a fundamental component of an online learning activity, this is yet another hint towards the third scenario of the previous subsection. A proper redesign of the course to make it into an ILF would be first step after the analysis is completed.

## 5 Conclusions

A significant correlation has been observed between passing the test at the end of the remedial course and passing the exam for the 310 freshmen of the 2018–2019 academic year we considered. We have not enough evidence of a causation: interviews would have helped, but COVID-19 prevented them. Elaborating the same data with the 2019 class could confirm or disprove the results: unfortunately, COVID-19 hampered significantly such an intent: only one exam was administered before lock down came into effect, and at the very least three exams will have to be administered online: such a change could render all comparison moot.

## 6 What comes next?

A completely redesigned at-distance remedial course was offered in August 2020, while this paper was under revision: 112 students took part and — using the proposed definition of success — it was indeed very successful (an expanded abstract has been proposed for publication).

## 7 Acknowledgements

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