Online Tutoring in Introductory Physics Courses: a Lockdown Experience

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(Dated: November 30, 2020)

Social distancing due to the Covid-19 pandemic deeply impacted on education worldwide, since schools and universities had to rapidly organise lessons and courses on line. Traditional interactions between teachers and students and, also among students, had to change and was substituted by on line connections. In this context, laboratory work and tutoring, which have an important role in the peer instruction model, needed to be redesigned. Here, we discuss an on line tutoring model adopted for the introductory physics courses at Turin Polytechnic University and evaluate its effectiveness by analysing the students performance both during the semester and the summer and autumn exam sessions.

I. INTRODUCTION

The impact of the ongoing Covid-19 pandemic on education is without precedents since, overnight, it deeply changed teaching methods and organisations for billions of students and teachers around the world. Schools and universities had (and still have) gigantic challenges to adapt their classes to distance learning as quickly as possible, in order to keep educational continuity.

Besides the obvious difficulties - both for teachers and students - due to the switch in a very short time to on line courses, there was an additional complication for the learning process, provoked by the atypical situation [1–4]. In fact, because of social distancing, interactions with teachers and peers considerably changed, and, de facto, students were forced to experience independent study much more than in the past [5]. Accordingly, the role of teachers and students became different from those in a traditional learning process: in this case teachers cannot directly interact with students and just act as facilitators to support them, while students have to independently develop their collaborative efforts [6]. Fortunately, due to the development of the Internet and related technologies, today’s students have devices such as smartphones, tablets and personal computers available. These technologies make it possible and easy to access large volumes of information and to maintain contact with classmates and educators. Undoubtedly, if this pandemic had spread only 30 years ago, its effect on education systems worldwide would have been devastating.

In addition, activities such as laboratory work and tutoring were greatly limited during the pandemic and they had to be re-designed in order to be effective in the learning process. These activities have an important role in the peer instruction model, whose effectiveness is well known, from early childhood education [7] up to college [8] and university level [9, 10]. In the literature peer collaboration refers to laboratory work and peer tutoring to a tutoring model in which advanced students (“student-tutors”) or those in later years take on an instructional role (see e.g. Boud et al. [11], Collings et al. [12]), mainly aimed at the revision of the taught content. Peer tutoring has several advantages, as reported by Sneddon [13]: for instance, students are freer to communicate with each other in the absence of teachers; student-tutors have an approach to the course materials and resources which is more similar to the student one; the interaction between students and student-tutors is more direct and personal which can lead to a more lively and open learning environment. Usually, in this model there are meetings two/three times per week, in which one or more student-tutors works with a small number (ranging from 50-100) of students. There is evidence that in this model both the tutees and the tutors get benefits [13].

Social distancing provoked by the pandemic acts as a serious deterrent for carrying out peer tutoring which is typically intended for weak and less experienced students. For these reasons it is necessary to completely redesign this model of tutoring, and the same, of course, holds true for laboratory work [11, 15].

In this paper we report the results of an on line tutoring model developed for the introductory physics courses at Turin Polytechnic University during the lockdown due to the Covid-19 pandemic. The tutoring was based on on line activities, both synchronous, such as video and chat sessions, and asynchronous, such as questionnaires and exercises. The former were conducted by student-tutors and organised by staff members. These activities aimed to facilitate the students’ learning process and, also, to mimic the classroom interactions that were not allowed. In this work we aim to evaluate the effectiveness of the tutoring model by analysing the performances of the students involved, both during its progress and during their...
The paper is organised as follows: in Section II we describe the tutoring model and the context, while in Section III we examine the methodologies and give the results, which are then discussed in Section IV. Conclusions are eventually drawn in Section V.

II. THE ONLINE TUTORING MODEL

Turin Polytechnic University (TPU) is one of the most important Italian Technical Schools for Engineers and it attracts students not only from Italy, but also from more than 100 countries around the world; about 45% of students come from outside Piemonte, the region where Turin is located, and 15% come from abroad. About 5000 students start studying at TPU every year, and during the first year they are divided into 20 courses: 18 are taught in Italian and 2 in English. The students in the Italian courses are divided by alphabetical order rather than ability. During the first year, students attend the “Physics I” course, which is an introductory calculus-based course including classical mechanics and thermodynamics, Newtonian gravitation and basic electrostatics in which Coulomb’s and Newton’s law are compared. In each course, there are between 300 and 500 students: besides first year students, there are also students who did not succeed in passing the exam from previous years. As a consequence, each year there are approximately 10000 students in the Physics I courses.

The Physics I course is generally considered as difficult and among those which most frequently contributes to dropping out of TPU. Consequently, TPU organises tutoring activities to help students, in the spirit of the Learning Assistants scheme, developed by the University of Colorado [16], where experienced students (usually 2 years older) are employed as tutors and, together with course lecturers, they revise the key topics. Usually, student-tutors work in pairs, and meet small groups of students once or twice per week. The interaction is direct and immediate and mainly involves solving exercises.

The Physics I course is taught during the second semester of the academic year, which usually starts between the end of February and the beginning of March, so in 2020 overlapped with the outbreak of the Covid-19 pandemic in Italy. Due to the emergency situation, all courses were switched to online delivery at TPU and the usual tutoring in conditions of social distancing could no longer take place; consequently, it was necessary to design a new online tutoring model.

The model we developed is based on a Moodle platform, integrated in the Internet TPU portal, which is accessible to all Physics I students; 20 student-tutors (here and henceforth junior tutors) were recruited and coordinated by 4 TPU staff members (here and henceforth senior tutors), who were lecturers in the Physics I courses. The junior tutors were divided into 10 pairs and each pair was assigned to two courses. The activities described here refer to the courses taught in Italian only because, due to the very short time available to organise the tutoring, it was not possible to involve the 2 courses taught in English.

The weekly activities began one month after the beginning of the courses and were organised as follows (see also Figure 1). (1) Senior tutors prepared a set of multiple choice questions on selected issues from the lectures; these questions were about important concepts or aimed to eliminate typical misconceptions. (2) Students were invited to answer the weekly questionnaire during the weekend. (3) On the basis of the results, senior tutors prepared specific

![FIG. 1: Tutoring weekly plan.](image)
exercises in order to address common errors. (4) The exercises were discussed on the following Monday during an online meeting between senior and junior tutors: the aim of the meeting was to inform junior tutors about the students’ results in the previous questionnaire in order to outline the expected errors for the proposed exercises. (5) Each tutoring group had two weekly sessions (scheduled on different days at different times in order to give all the students the possibility to attend the class); in each session the same exercises were used. The interactions with the students during the tutoring sessions took place in the chatroom of the videoconferencing system and, also, using dedicated Telegram channels. Each session was divided into two parts. In the first part, students had time to go through the proposed exercises on their own, in the second part the exercises were solved by the junior tutors. All tutoring sessions were recorded and, then, made available on the Moodle platform, together with the exercises and their solutions. (6) Students were requested to complete the same questionnaire (with the same questions) after each tutoring session in order to measure the impact of the tutoring activities.

The tutoring was organised over 8 weeks (plus 1 for revision of mechanics) and the topics covered the whole content of the Physics I course, in the following sequence:

- Week 1: Mathematical prerequisites
- Week 2: Kinematics
- Week 3: Dynamics
- Week 4: Conservation laws and collisions
- Week 5: Rigid body
- Week 6: Gravitation and electrostatics
- Revision of Mechanics
- Week 7: Calorimetry and first law of thermodynamics
- Week 8: Second law of thermodynamics

The entire tutoring lasted for 9 weeks, with 18 tutoring sessions per group. The whole set of activities was recorded both on the Moodle platform and on the Telegram channels: they are currently being analysed and will be discussed in a forthcoming paper [17]. In this work, we focus on two research questions that are important to evaluate the effectiveness of this tutoring model, both during its progress and in the final exams, namely:

Q1: As a result of the weekly activities performed and of the interactions with the junior tutors, is there an improvement in the results of the questionnaires?

Q2: As a result of the participation in the tutoring activities during the semester, is there an improvement in the marks among the students who attended the tutoring, with respect to the average results of all students?

These research questions will be discussed in the following Section.

III. METHODOLOGIES AND RESULTS

The average number of students who attended the tutoring sessions every week, as registered by the junior tutors, was 385: this was the sum of the 9 tutoring groups, which means more or less 43 students per week per group. These data are aggregate, so the number of presences was not equally distributed in each group and the same students did not attend all sessions. Nonetheless these data give an idea of the synchronous interactions which occurred during the tutoring. Interestingly, the number of asynchronous interactions was far greater than the average number students attending (385): in fact by the end of the summer exam session, we had registered about 9000 students on the Moodle platform. Even though the tutoring ended at the beginning of June, students continued to use this platform after this date for the video recordings of the tutoring sessions, for the solutions of the problems proposed and for repeating the weekly questionnaires.

The following analysis refers to all data collected until the end of September, after the end of the summer and autumn exam sessions. Firstly, we analyse the weekly questionnaires, in order to track improvements in the students’ performance. Subsequently we compare the exam results of the students who attended the tutoring to those achieved by all students.

A. Weekly Questionnaires

The weekly questionnaires, one before the tutoring sessions, and one after the tutoring sessions, were completed on a voluntary basis. Only one attempt was allowed for both questionnaires. In Figure 2 we report the number of students who filled out both questionnaires in each week. This number is smaller than the number of students who answered each single questionnaire. For instance, during the first week 20% of students repeated the test after the tutoring session; in the subsequent weeks the percentages are 32%, 38%, 36%, 34%, 22%, 29% and 23%.

In Figure 3 we compare the percentages of correct answers of the pre and post tutoring questionnaires. To measure the students’ performances after the tutoring session, we calculated the Hake normalised gains (re-
FIG. 2: Number of students, per week, who carried out both the pre and the post tutoring questionnaires.

FIG. 3: Comparison between the percentage of correct answers in the pre and post tutoring questionnaires, together with the corresponding gain (g).

FIG. 4: Description of the sample analysed: number of sessions attended.

The gain is defined as the ratio of the actual average gain to the maximum possible average gain.

B. Final Exams

More specific data about the tutoring were obtained by an online survey administered to all students on the Moodle platform: we collected 1209 answers. The survey covered various areas, such as the numbers of sessions attended, the most interesting topics for students, the perceived effectiveness of the methods and informations about the interactions with the junior tutors.

The number of attended sessions is shown in Figure 4. We see that 403 students did not take part in any session: they did not attend the synchronous activities but they attended the asynchronous ones, such as watching the video recordings, completing the questionnaires, downloading the problems and so on. Hence, in the following analysis, the sample size is \(N = 1209 - 403 = 806\) students, given by the number of students who attended at least one tutoring session. We examined their performances in the exams of June, July and September.

As we can see looking at the distributions in Figure 5 and Table I, the average mark in the preliminary multiple choice test is higher for the sample of students who attended the tutoring sessions: this positive trend is evident in all exam sessions. In order to quantify the statistical significance of the difference between the average marks, we decided to perform a T-test and to evaluate the p-value. In our case the null hypothesis is: there is no statistical difference among the average marks of the two samples, their difference is due to a statistical fluctuation.
| Session | Sample             | Quizzes Attempted | Quizzes Passed | Percentage of Quizzes Passed | Average Mark |
|---------|--------------------|-------------------|---------------|-----------------------------|--------------|
| June    | Tutored Students   | 742               | 607           | 81.81                       | 10.02        |
|         | All Students       | 3522              | 2557          | 72.60                       | 9.31         |
| July    | Tutored Students   | 411               | 354           | 86.13                       | 10.04        |
|         | All Students       | 2636              | 1908          | 72.38                       | 8.99         |
| September | Tutored Students | 195               | 157           | 80.51                       | 9.72         |
|         | All Students       | 1870              | 1325          | 70.86                       | 9.02         |

**TABLE I: Details of June, July and September exams.**

The T-test was carried out on the basis of the statistical parameters reported in Table II. In all cases (June, July and September sessions) the resulting p-value is smaller than 0.001, meaning that we have a confidence level bigger that 99.9% to reject the null hypothesis. In other words, the different average marks of the two samples are not due to statistical fluctuations.

From the data in Table II, we see that the marks of the students from tutoring are, on average, 0.8 points higher. It is important to emphasise that, even if this result might seem to be negligible, it has significantly decreased the number of student failures (grade < 8) in the Physics I course. By comparing the percentages of students with a grade lower than 8, we can evaluate the improvement in the rate of successful students (see Figure 6). In June the percentage of Tutored students not passing the test was lowered by 9%, in July by 14%, in September by 10%. If we apply the average 11% improvement to the number of students attending the Physics I courses each year (∼10000), the tutoring activities would lead to an increase of about ∼1000 in the number of successful students in the preliminary test.

**IV. DISCUSSION**

Despite the low completion rate for the questionnaires, a small improvement in the student marks was evident (see Section III A). The average weekly attendance was 385 students and in the best case (Week 2), only 142 stu-
In conclusion, even though we know that further improvements are needed, for instance to stimulate a...
FIG. 6: Comparison among the total percentage of rejected students in the preliminary test. In all exams sessions, the sample of students from Tutoring shows a lowered percentage.

greater participation, we believe that it was important to give the students the possibility of experiencing the peer education model through the tutoring activities, during the lockdown. Moreover, the improvement in the students’ performances were encouraging and suggests the effectiveness of this tutoring model.

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