Using Information and Communication Technology Tools to Enhance Traditional Electrical Engineering Education

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Examining Accesses to Educational Resources in a Blended Learning Flipped Classroom Controls Course in 2020

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Abstract. The Controls and Servomechanisms course is mandatory for students in two Enginering curricula - Control & Automation and Electrical.

In 2020, it was supposed to be offered in the Blended Learning (b-learning) and flipped classroom mode as it had been in the past. Many courses in the two curricula use this mode. Due to the pandemic, the university switched to totally remote activities and, for this reason, the synchronous sessions had to be held using a videotelephony solution. This meant that online courseware became more important and its usage an indicator of the participation of students. The same happened with discussion forums since instructors and students had to use them to communicate off class hours. This work addresses the use of both courseware and discussion forums in 2020, and relates this use to the grades of students. All data are collected from the platform used to support the course. Data are presented as percentages, averages and histograms.

Keywords: Accesses to Educational Resources, Blended Learning, Flipped Classroom.

1   Introduction

This work presents results of the use of Blended Learning (b-learning) [1] associated Flipped Classrom in an undergraduate Controls and Servomechanisms course in 2020. The course had special characteristics because it had already been taught in this mode for four semesters before going back to the traditional face-to-face mode. After seven semesters in the traditional mode, it was scheduled to return to b-learning with flipped classroom in 2020.

This yielded a comfortable situation when the University decided to go completely remote in March 2020 due to the COVID-19 pandemic. The number of synchronous activities was already reduced, courseware in digital formats (online and offline) was abundant and the infrastructure to host both was ready.

This work has two objectives. The first is to address tha usage of the different types of Educational Resources (ER) by the students in the classes that were taught in the first and second semesters of 2020; this means during the pandemic. The types of ERs are: texts, videos, interactive objects (hypermedia, simulators, online exercises), software and the discussion forums. Forums were included as resources because they yield a space where problems can be discussed and results can be posted and made available to all students. In this analysis, the preferences – digital instances of conventional learning resources (texts and videos) as compared to online interactive materials – are identified. The second is to examine accesses to contents (in numbers), par-

ticipation in the discussion forums and grades at the end of the term. All data are statistical – percentages, averages and histograms.

B-learning is used following the definition given in Table 1.

Table 1. Prototypical Course Classifications – page 5of Allen and Seaman [1].

Proportion of Content Delivered Online	Type of Course	Typical Description
0%	Traditional	(1)
1 – 29%	Web Facilitated	(2)
30 – 79%	Blended / Hybrid	(3)
80+%	Online	(4)

(1) Course with no online technology used – content is delivered in writing or orally.

(2) Course that uses web-based technology to facilitate what is essentially a face-to-face course. May use a course management system (CMS) or web pages to post the syllabus and assignments.

(3) Course that blends online and face-to-face delivery. Substantial proportion of the content is delivered online, typically uses online discussions, and typically has a reduced number of face-to-face meetings.

(4) A course where most or all of the content is delivered online. Typically has no face-to-face meetings

Flipped classroom is defined at The Univeristy of Texas at Austin Faculty Innovation Center (https://facultyinnovate.utexas.edu/instructional-strategies/flipped-classroom) as:

"A flipped class is one that inverts the typical cycle of content acquisition and application so that:

- Students gain necessary knowledge before class, and
- Instructors guide students to actively and interactively clarify and apply that knowledge during class."

In this work, b-learning and flipped classroom mode will be referred as b-learning implying flipped classroom is used too.

The time frame of the analysis is 2020.1 and 2020.2, respectively the first and the second semesters of the school year 2020.

This work has 3 sections besides this Introduction. Section 2 presents the context of the University. Section 3 addresses accesses to Educational Resources (ER), participation in discussion forums and grades. Section 4 comments on the results.

2   The Context

2.1   The University and ICT Enhanced Learning in Engineering

Pontifícia Universidade Católica do Rio de Janeiro (PUC-Rio) is a small confessional university located in Rio de Janeiro, Brazil. It offers undergraduate, graduate and extension courses, and is very active in research.

Beginning in August 1995, faculty in Electrical Engineering started using ICT – Information and Communicaion Technology tools to enhance learning and teaching. The platform to support it, Sistema Maxwell (https://www.maxwell.vrac.puc-rio.br), was created then. It is important to remember that 26 years ago IT was a lot more limited and the speed of the Internet much lower. This was no doubt a limitation but at the same time if offered a huge space for growth and enhancement.

As time went by, the evolution showed good results. Some to be mentioned are: (1) the number of instructors grew, though not at the rate that was desired – there still is a lot of resistance, a topic to be adressed later on; (2) IT tools changed at an astonishing rate; (3) the speed of the Internet kept in pace with IT tools; and (4) the international scenario changed a lot and could be used as a showcase to bring faculty to the group.

The main results of the actions taken by the group can be summarized in: (1) development of courseware both in Open Access and restricted; (2) evolution of Sistema Maxwell to become a completely integrated platform [2, 3] hosting an IR – Institutional Repository [4], an LMS – Learning Management System [5] and Remote Labs [6]; (3) adoption of Remote Labs – Visir [7] in 2016 and a cargo elevator in 2021; (4) deployment of the aggregator Open Educational Resources @PUC-Rio (https://www.maxwell.vrac.puc-rio.br/projetosEspeciais/OER/index.php) to offer OER – Open Educational Resources created at the University; (5) adoption of b-learning and flipped classroom in some core courses of the curricula of Control & Automation and Electrical Engineering in the first semester of 2014 [8, 9] – when faculty change, the learning/teaching mode may be discontinued since there is not an institutional policy, this is a topic to be addressed later on too; and (6) easy migration from the b-learning with synchronous sessions in brick and mortar classrooms to b-learning in which the synchronous sessions are held via Zoom (https://zoom.us).

2.2   The Controls and Servomechanisms Course

The Controls and Servomechanisms course is mandatory in two Engineering Curricula: Control & Automation and Electrical. It is a 6 credit course that is simultaneously taken along a 2 credit Traditional Lab course. The prerequisites to both are Linear Algebra II and Signals & Systems. The syllabus contains topics in both Classic and Modern Control, and Continuous Time as well as Discrete Time Systems.

The course is offered every term and the average number of students is between 20 and 30.

It started being taught in the b-learning mode in the second semester of 2014. This mode was maintained during four semester with two diferent instructors. In the second semester of 2016, a new instructor was admitted and returned to the traditional [7] mode. When this instructor left the university, the course returned to b-learning. It

was March 2020, when the University switched to remote learning/teaching due to the pandemic. Since the return to b-learning had been decided in 2019, it was planned to develop new online courseware to be added to the existing materials.

In order to help students map the topics of the syllabus they have already accessed materials (and the ones lacking), a Knowledge Map (K-Map) [10] of the syllabus and supporting materials was implemented on the platform. K-Maps are extensions of Concept Maps (C-Maps) [11] and were used to allow materials to be added to Concepts. For students to be able to track their progress on topics and materials, a program was developed on the platform to allow students to check among materials in each topic the ones already acessed. Fig. 1 shows the map of test student "alunomaxwell" as of March 27, 2020. A link to Cmap Tools (cmap.ihmc.us/) was indicated so that students could draw their own maps; accesses to the link were tracked.
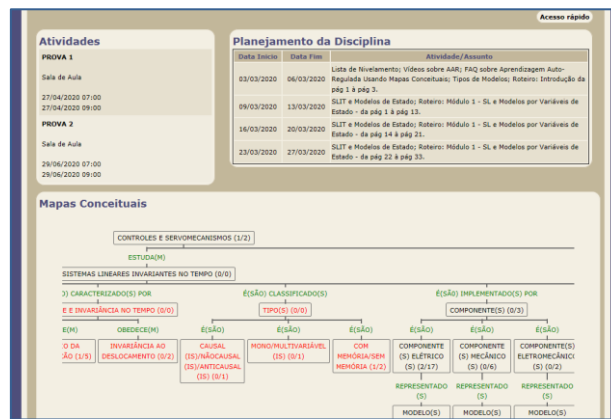

Fig. 1. A segment of the C-Map/K-Map of test student "alunomaxwell" shown along with *Atividades* (Activities) and *Planejamento* (Course Schedule) as of March 27, 2020.

Since 2020.1 the course has been taught in the b-learning mode.

2.3   The Courseware to Support the Controls and Servomechanisms Course

The development of courseware began in August 1995. Due to technological limitations, courseware was very simple – html files with images and short animations. The speed of the Internet was low so video was not used. As time went by, the evolution of ICT allowed the enhacement of the materials. A second important factor was the international context that was under evolution. One example is MERLOT – Multimedia Resources for Learning and Online Teaching (https://www.merlot.org) that started in 1997 and currently offers over 94K materials. Another example is the introduction of MOOC – Massive Open Online Courseware in 2007, as presented by Prof. S.L. Mora of Universidad de Alicante in the vídeo *Breve (Muy Breve) Historia de los MOOCs* (http://desarrolloweb.dlsi.ua.es/moocs/brief-history-moocs).

Since 1995, courseware has been developed at PUC-Rio. Faculty involved in the activity are from Control & Automation and Eletrical Engineering, for this reason most courseware addresses topics in these areas. Materials used in the Controls and Servomechanisms course are divided in the following groups:

- Hypermedia Resources and Software:
  - Course Guide – a large hypermedia file that outlines the topics of the syllabus presenting definitions, suggesting activities, linking to online courseware both on the Maxwell Platform and on other sites (when in Open Access) and containing 23 vídeos. It is divided in sections that address all the topics of the syllabus. The Course Guide is restricted. It is currently in version 3.
  - Online Learning Objects (LOs) – courseware that must be used online and that can be hypermedia interactive objects or simulators. In both cases, the object offers a theoretical presentation of the topic and animations, videos, quizzes, etc. The simulators have the same theoretical characteristics but they run code developed using Scilab (https://www.scilab.org/) which was integrated to the Maxwell Platform in 2015. All LOs are in Open Access. The number of LOs increases each term because the team keeps developing them. An important fact about the LOs is that all of them have students (undergraduate or graduate) as authors or coauthors.
  - Software – the software is Cmap Tools whose link was made available and accesses to it were counted.
- Texts – class notes and suggested problems (for individual study and for discussion and solution in the synchronous sessions). PDF files of the MS Power Point presentations used for the synchronous sessions are included. Texts are restricted.
- Videos of the synchronous sessions and a video on Cmaps – the videos of the symchronous sessions (of the term) were made available as references. A video about Cmaps and how to use the was created for the course. Vdeos are restricted.

The numbers of materials available in each term are shown in Table 2.

Table 2. Numbers of Materials by Group in Each Term.

Term	Group	Number
2020.1	Course Guide	1
	Texts	29
	Learning Objects and Software	60
	Videos	16
2020.2	Course Guide	1
	Texts	53
	Learning Objects and Software	85
	Videos	14

Besides courseware, the course uses discussion discussion forums for students and faculty to communicate. The discussion forums are divided in topics according to the activities along the term.

The numbers in Table 2 increased from the first term to the second due to two situations. The first was the development of more materials and the second was the identification of additional materials on the platform that could enhance the course.

3 Accesses to Courseware, Participation in the Discussion Forums and Grades

This section has three objetives. The first is to address the usage of learning materials by the students in each class. The second is to examine the participation in the discussion forums. The third is to relate both to the grades.

Two dimensions of accesses were considered for the non forum resources: (1) the numbers different ERs accessed in each group; and (2) the numbers of accesses to each accessed ER. The platform offers logs for each student. Each was independently examined to count accesses and later on to relate to the forums and grades. The platform also offers reports of participation in the discussion forums.

Results are presented as statistical data as already mentioned. The semesters under consideration are not typical since the ERs included the videos of the classes on the Zoom platform which had not happened to any of the b-learning offerings before the pandemic.

The numbers of students were 19 (2020.1) and 21 (2020.2).

3.1 Accesses to Courseware

In order to generate data, a spreadsheet was created for each classs. Students were listed and results from the platform logs were written. Data on accesses to courseware, discussion forums and remote experiments are available to all instructors (for their classes) as functions of the system.

In each spreadsheet there were two sets of columns: (1) accesses to different ERs in each group; and (2) numbers of accesses to the accessed ERs. In the first set data were computed as percentages and in the second as averages. Each set of columns contained columns for each group of ERs. In the second set of columns, average accesses to the Course Guide were computed separately since it was expected that students would access it at least once a week; this did not happen though.

Fig. 2 and 3 show the percentages of accessed resources in each of the three groups in the two semesters under consideration. In both, it is clear that texts had more accesses than the other two and that interactive courseware (LOs) were the least accessed.

What would a possible interpretation be? Two aspects can be considered and they are not mutually exclusive: (1) texts are similar to the usual references students have used for many years; and (2) texts contain assignements, exercises, etc. If the stu-

dents' main goal is to pass the course, texts seem to be the default option. At the same time, videos are similar to traditional classes, specially the ones that are recordings of the synchronous sessions. In the b-learning flipped classroom mode, synchonous sessions are devoted to discussions and problem solving, so watching the video of a session does not "hit the target", it does not allow participation and interaction.
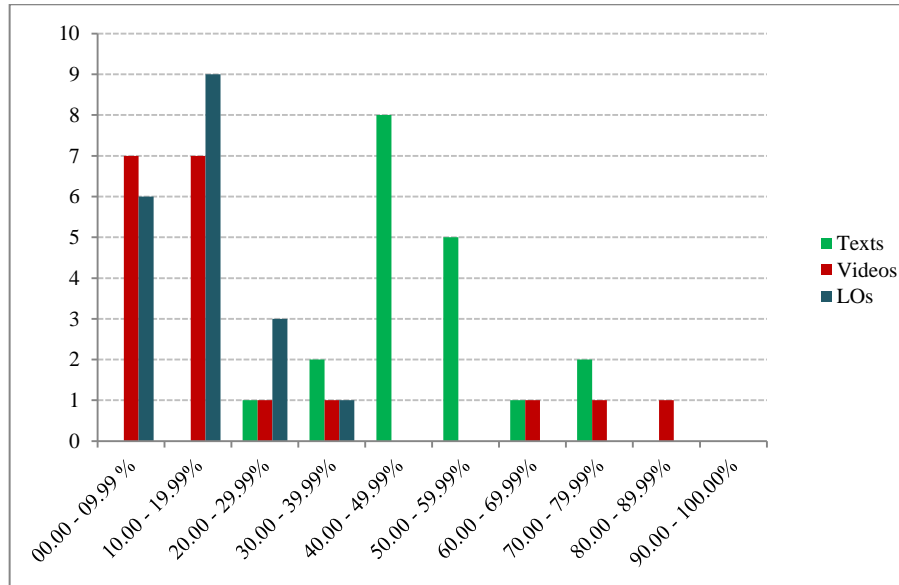

Fig. 2. Numbers of students per percentage of accessed resources in each of the three groups of ERs in 2020.1. There were 19 students in the class.
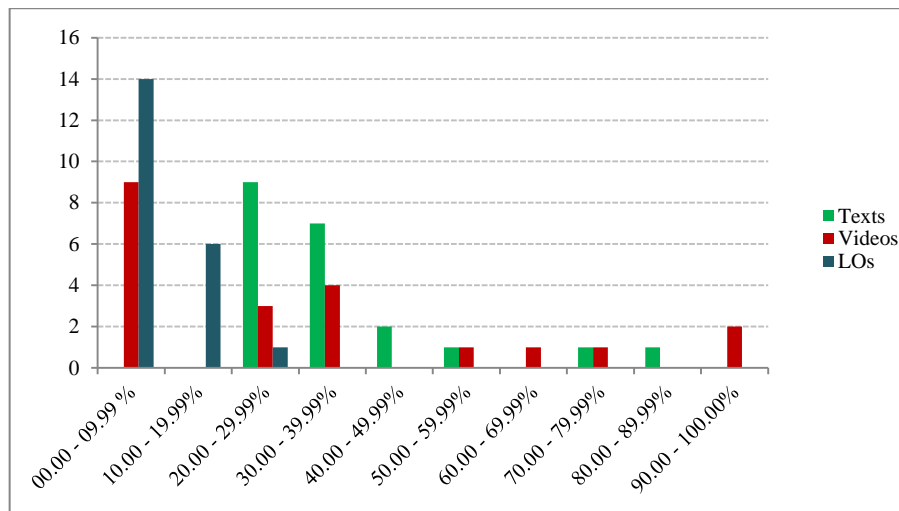
Fig. 3. Numbers of students per percentage of accessed resources in each of the three groups of ERs in 2020.2. There were 21 students in the class.

When raw data are examined interesting numbers are obtained: (1) the averages of the percentages of accesses considering all students and all resources were 24.85% in the first semester and 22.56% in the second; (2) the averages of percentages of accesses considering all students and only texts were 49.55% and 36.31%; and (3) the averages of percentages of accesses considering all students and only videos were 20.35% and 29.67%. When numbers for texts and videos are added, the results respectively are 69.90% and 65.98%.

Fig. 4 and 5 show the average numbers of accesses to accessed resources in each of the three groups and the Course Guide in the two semesters under consideration.

The two computations aimed at examining how "wide" were the students interests, Fig. 2 and 3, and also how "deep" they were, Fig. 4 and 5.

The Course Guide was implemented to suggest the order of topics to study, which materials support different topics and, most important, activities to perform in order to make sure concepts were understood and methods learned. The Course Schedules in all semesters assign topics of the Course Guide for each and every week. For these reasons, the author expected that accesses to the Course Guide should happen at least once a week. Considering that the length of the school semester is 15-16 weeks, this was the minimum number expected for the average accesses. This is not what happened. Fig. 4 and 5 show that this number is not spread among all students. Some had higher numbers of accesses and the averages were 16.44 (one student never accessed and was disconsidered) and 8.68 (two students never accessed and were disconsidered); numbers are for 2020.1 and 2020.2, respectively.

Besides the Course Guide low numbers of accesses, average accesses were low. When texts are considered this can be explained by the fact that students can download the texts to study offline. On the other hand, online interactive LOs must be used online and the numbers are quite low too.
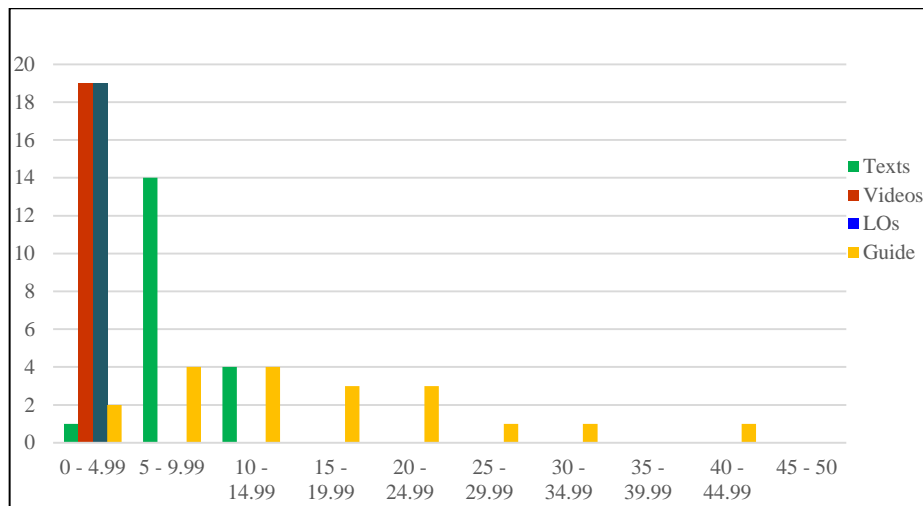
Fig. 4. Numbers of students per average numbers of accesses to accessed resources in each of the three groups of ERs and Course Guide in 2020.1. There were 19 students in the class.
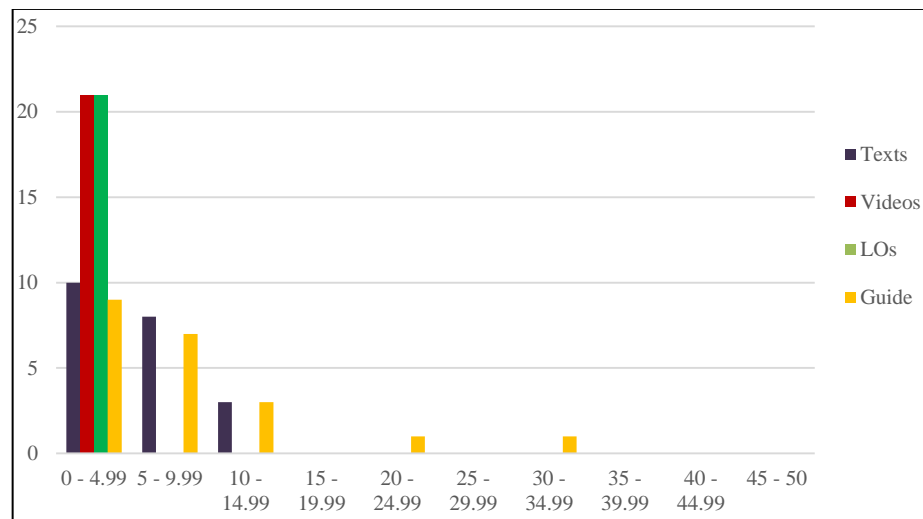

Fig. 5. Numbers of students per average numbers of accesses to accessed resources in each of the three groups of ERs and Course Guide in 2020.2. There were 21 students in the class.

3.2 Participation in the Discussion Forums

Discussion forums are important components of the b-learning mode. They became more important when all activities were remote due to the pandemic.

In the first semester, three discussion forums were used and in the second the number was four. This happened due to the need to split discussions/doubts on the assignemnts from discussions/doubts during classes. In order to be able to compare the two classes, all forums in each term were treated as one and all participations were be added.

Fig. 6 and 7 show the numbers of students by the numbers of participation in the forums.
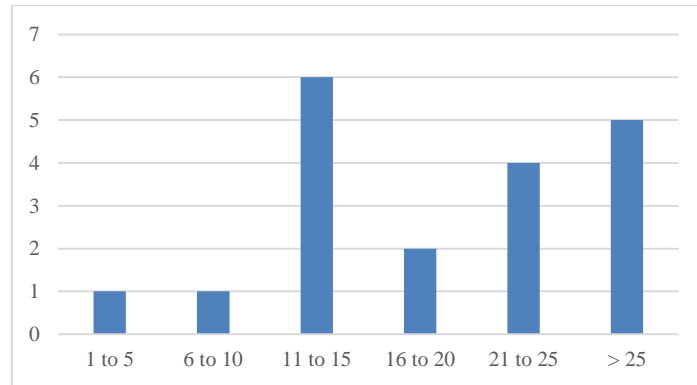
Fig. 6. Numbers of students numbers of participations in the discussion forums in 2020.1. There were 19 students in the class.
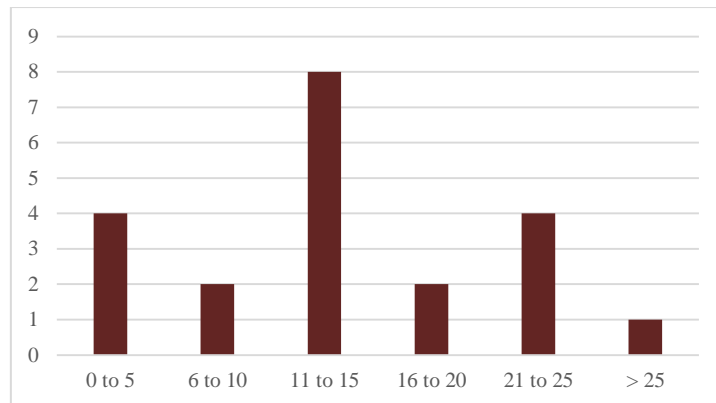

Fig. 7. Numbers of students numbers of participations in the discussion forums in 2020.2. There were 21 students in the class but one did not participate in the forums.

The histograms of Fig. 6 and 7 are quite different. Analysis of the raw data yielded interesting numbers: (1) the average numbers of participations were 22.74 in 2020.1 and 16.65 in 2020.2; and (2) all students in the first semester class participated while one in the second did not – this student was discarded when the average was computed.

3.3 Grades and Their Relations to Accesses to Educational Resources and Participation in Discussion Forums

The last step in data examination relates the final grades students had in the course to their accesses to ERs and their participation in the discussion forums.

Since all data are presented in percentages, averages or histograms, this sections relates grades to accesses to ERs and to participation in the discussion forums the same way. Tables 3 and 4 show grade intervals, numbers of students in each one,

averages of accesses and of participations in the forums by the students in each grade interval.

PUC-Rio uses a grading system from 0.0 to 10.0 and the passing grade is 5.0.

Table 3. Grades, Accesses to ERs and Participation in the Discussion Forums in 2020.1.

Grades	# of Students	Average Accesses ERs	Average Participation in Forums
9.0-10.0	9	213.44	31.44
8.0-9.0	7	154.00	15.57
Fail	3	112.67	13.33

It is curious that in 2020.1 16 out of 19 students (84.21%) got final grades between 8.0 and 10.0. This did not happen in 2020.2, as shown in Table 4.

Table 4. Grades, Accesses to ERs and Participation in the Discussion Forums in 2020.2.

Grades	# of Students	Average Accesses ERs	Average Participation in Forums
9.0-10.0	2	103.50	07.50
8.0-9.0	7	113.86	24.57
7.0-8.0	5	104.60	15.40
6.0-7.0	5	90.40	10.40
5.0-6.0	1	33.00	06.00
Fail	1	23.00	11.00

Numbers in both tables seem to indicate that higher grades are associated to more participation – the exception is the first row of Table 4. More participation being associated to better results is not a surprise.

4   Final Comments

The compilation of data and their crossreferencing (accesses to ERs, participation in dicussion forums and grades) was somehow revealing of the profile of students participation using materials and interacting with peers and/or the instructor.

A disappointing result of the compiled data is the low usage of the interactive online ERs. Since current students are very motivated to use software and websites in their everyday activities, it was an expectation that the numbers would be higher.

Since the course had been taught in the traditional mode for seven semesters before 2020.1, there were not uptodate data to compare.

In 2021.1, the course is being taught in the b-learning mode. New ERs have been added to the collection and to the list o recommended materials. When school is over in about a month, data will be compiled again to compare to the results shown in this

work. The accesses to ERs have been computed in terms of percentages of the offered materials, so higher numbers do not change the analysis.

A final comment relates to the resistance some faculty show in changing the learning/teaching mode and adding more interaction and participation by the students. This leads to the situation that new learning/teaching modes are discontinued when instructors change due to the fact that there is not an official recommendation on this matter. Since the pandemic forced deep changes, it is expected that some of them will permanentely be incorporated to the institutional culture.

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