Does Online Content Support UML Learning? An Empirical Study

Adriano Santos, Gustavo Vale, Eduardo Figueiredo

Software Engineering Laboratory (LabSoft), Department of Computer Science (DCC), Federal University of Minas Gerais (UFMG)
Belo Horizonte, Brazil

{adriano, gustavovale, figueiredo}@dcc.ufmg.br

Abstract. *Open online courses are a method of online lecturing whose application in education is not bounded by space and location constraints. The successful implementation of open courses requires conceptual changes in how instructors and students behave in open unbounded education environment. Common features available in online courses are video lectures and online questionnaires. However, there is little knowledge on the efficacy of these features to support learning of software modeling in UML. To fill this gap, this paper presents an empirical study to evaluate whether online content supports learning of UML diagrams, such as Use Cases, Class and Sequence Diagrams. This study involved 193 students in three consecutive years of a Software Engineering course. All students had face-to-face lectures, but features of online teaching were gradually included: video lectures in the 2nd year and online questionnaires in the 3rd year. Student performance was assessed based on their grades in the course face-to-face exams. Our results indicate that students who answer online questionnaires have better grades in face-to-face exams. However, we could not always verify improvements in the performance of students due to video lectures watched.*

1. Introduction

Internet has become an important tool to modify education through open online courses. An open online course creates an educational environment not bounded by space and location constraints [Fox and Patterson, 2012]. The success of open online courses requires conceptual changes in the way as lectures and students behave in such an open unbounded environment [Fox and Patterson, 2012; Liyanagunawardena et al., 2012]. Supporters of open education claim that the online content, such as video lectures and online questionnaires, is an important tool in the learning process. In some sorts of open courses, students can join classes at any time, do exercise, read past discussions, and so on [Schimidt and McCormick, 2013]. Such innovation in terms of education allows discussion-oriented classrooms, i.e., face-to-face classes are dedicated for questions and activity solutions with closer interaction between students and teachers.

Several respectful universities around the world, mainly in North America and Europe, are providing open online courses based on to their face-to-face equivalent courses. These courses have attracted great attention of hundreds of thousands of worldwide students [Fox and Patterson, 2012; Schimidt and McCormick, 2013; SaaS, 2015]. For instance, Harvard University and Massachusetts Institute of Technology have invested on the creation of various online courses by the edX[1] portal. In addition, more than 80 American and European universities, such as Princeton and Stanford, are involved on creation of hundreds of online courses in several areas by means of Coursera[2]. Many other courses have been successfully created in Udacity[3] and similar open learning portals, such as Udemy[4]. In addition to video lectures, students regularly registered in an online course can answer online questionnaires and have an assessment of their performance. In some courses, a student who successful completes the course obtains a certificate or statement of accomplishment.

There are a couple of online courses to teach subjects related to Software Engineering [Schimidt and McCormick, 2013; SaaS, 2015; Tilmann et al., 2013]. However, these courses focus either on Pattern-Oriented Software Architecture [Schimidt and McCormick, 2013], Software as a Service [SaaS, 2015], Introduction on Software Engineering [Pereira et al., 2013; Figueiredo et al., 2014] or on how to program [Tilmann et al., 2013]. For the best of our knowledge, there is no open online course to teach software modeling using the Unified Modeling Language (UML) [Booch, Rumbaugh, Jacobson, 2005]. More important, there is no systematic study to investigate whether this way of teaching is efficient and viable to teach the basic concepts of UML, such as Class Diagram, Use Case Diagram, and Sequence Diagram. Therefore, it is essential for us to investigate and evaluate the actual benefits and drawbacks of online courses in order to understand whether and how such courses can indeed improve the learning of UML concepts.

Every year at the Federal University of Minas Gerais (UFMG) in Brazil, more than 100 students take a face-to-face Software Engineering course. Since 2013, an educational online platform is used to complement classroom lessons. Actually, this online course provides access to 44 online video lectures and 16 online questionnaires [Figueiredo et al., 2014]. Moreover, conversations between students and the course instructors are possible due to the discussion forums and emails, which provide a highly interactive virtual Software Engineering learning community. As part of this course, it is presented an introduction to UML. This part is important to the course and, it is responsible for about 20% of the course content (7 videos and 3 online questionnaires).

In this context, this paper evaluates the UML part of the Software Engineering course by comparing the performance of students over three consecutive years. Two features of online learning were gradually introduced to the course: video lectures in the 2nd year and online questionnaires in the 3rd year. Online questionnaires are commonly used by the students to review for the face-to-face exam [Garcia et al., 2014]. We evaluate the grades of exam questions related to UML of 193 students divided into 6 different semesters. Our results show that videos and online questionnaires contribute to the improvement of up to 20% of student grades in UML questions when compared with students who did not use videos and online questionnaires. However, based on two

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[1] http://www.edx.org/

[2] http://www.coursera.org/

[3] http://www.udacity.com

[4] http://www.udemy.com/

exam questions that repeated over four semesters, we verify that about 15% of grade improvement seems to be related to online questionnaires, rather than watched video lectures.

The rest of this paper is structured as follows. Section 2 presents some related work. Section 3 provides a background in some UML content and introduces the Software Engineering open online course. Section 4 presents the study settings, the evaluation of the UML content of the online course. Threats to validity are discussed in Section 5. Finally, Section 6 described our conclusions and future work.

2. Related Work

Many studies have been proposed to improve Software Engineering teaching [Liyanagunawardena et al., 2012; Dasarathy et al., 2014; Figueiredo et al., 2007; Figueiredo et al., 2014; Meirelles et al., 2011; Papaspyrou et al., 1999; Potter and Shots, 2011]. Most of these studies focus on software engineering and online courses, compated to traditional face-to-face courses in universities [Xie et al., 2013]. However, these studies do not analyze the impact of online environment on student learning of UML-related topics. We provide a different evaluation compared to related work because we focus on two common features of online support and their impact on grades of students regularly enrolled in a face-to-face course.

Ahmadi and Jazayeri (2014) discuss the process of student learning while the students are doing online activities. They analyze the results of online questionnaires and activities realized by students during an experiment. Nevertheless, the authors did not perform any comparison with the student results in traditional teaching methods.

Fox and Patterson (2012) offer a hybrid course (part online and part face-to-face) in Software Engineering, focused on test-driven development (TDD) and agile software development at Berkeley University. They report the use of agile development techniques to teach a face-to-face course with more than 100 junior and senior students at Berkeley University. Fox and Patterson (2012) also discuss their experience in providing the first part as an open course to 50,000 online students, most of who work in the IT industry. However, their paper does not present any assessment to verify whether the proposed online course has positive or negative aspects in the student learning. Unlike Fox and Patterson (2012), our work focuses on UML teaching.

Schmidt and McCormick (2013) propose a course to teach design and architecture patterns for development of concurrent and networked software systems. They focus on some specific topics in the long list of content covered by an introductory Software Engineering course. Similar to their work, we evaluate in this paper one facet of the Software Engineering discipline (UML diagrams) rather than the extensive course content. That is, we do not aim to assess learning of Software Engineering topics, such as software process, requirements engineering, and software maintenance.

Some studies [Ye et al. 2007] [Potter and Schots 2011] [Ahmadi and Jazayeri 2014] use open education as a complement to teaching Software Engineering. On the other hand, our work focuses on comparison of different levels of online support. We want to see what online supporting feature is more effective in helping students to learn UML diagrams.

3. Background

3.1. The Unified Modeling Language

The Unified Modeling Language (UML) is a general-purpose modeling language in the field of software engineering, which is designed to provide a standard way to visualize the design of a system [Booch et al., 2005]. UML is composed of two types of diagrams: behavioral and structural diagrams. Each diagram has elements that represent components, objects, users, modules, and states of a system. Figure 1 shows three elements of UML diagrams: a class `Account` of a Banking system, a `Manager` actor and an object `c` of class `Customer`. These elements are generally used in Class Diagram, Case Uses Diagram, and Sequence Diagram, respectively.

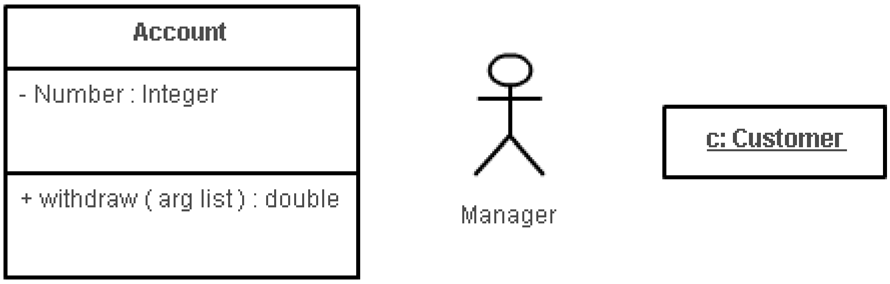

Figure 1. Elements of UML Diagrams

3.2. The Software Engineering Course and Our Preliminary Results

The online Software Engineering course was created in the first semester of 2013 [Pereira et al., 2013]. Initially, this course supported students of Federal University of Minas Gerais (UFMG) to learn concepts of Software Engineering. This course is free and based on two textbooks: *Software Engineering* [Sommerville, 2010] and *The Unified Modeling Language User Guide* [Booch et al., 2005]. It was make available online by using the Udemy platform. Udemy is a platform of online learning and management content that allows instructors create paid and free courses. By using Udemy, the instructors can provide video lectures, presentations, online questionnaires, and complementary files. The platform also allows that students discuss with others and with the instructors by means of discussion forums. Other features of Udemy include (i) annotations during the video lectures by students and (ii) statistics analyses for instructors.

Some results were presented to the community in previous work [Pereira et al., 2013; Figueiredo et al., 2014; Garcia et al., 2014]. The main results of our previous work can be summarized as follows: (i) students were engaged and motivated to participate in the online course, especially as a way to study for exams; (ii) exam grades of students in the face-to-face course with online support are significantly higher than the exam grades of students attending the same purely face-to-face course; (iii) frequency of students in the face-to-face course with online support was not a determinant factor for getting good grades; (iv) online questions with higher error rate are almost the same in more than one semester; (v) low correlation of correct answers in online questionnaires and the total number of videos watched; (vi) low to moderate correlation of online questionnaires with frequency; (vii) low to moderate correlation of correct answers in online questionnaires and exams.

The preliminary results served as a motivation for us to continue the work in this paper. In this sense, this study aims to assess the progress in other dimensions, focusing mainly on the level of online support in a specific part of the course (UML content). Our online course has an audience of about 300 students currently registered, but we are analyzing in this paper data of only 193 students enrolled in the university face-to-face course in the last three years.

4. Evaluation of the Software Engineering Online Course

The online education has brought new challenges and potential benefits to traditional education. This section aims to evaluate the benefits and drawbacks of online education in leaning of UML diagrams. Section 4.1 presents the study settings and procedures we followed. Section 4.2 analyzes the student performance per year. Section 4.3 discusses performance focusing on two recurring questions in exams. Section 4.4 correlates the presence in UML face-to-face classes with the exam grades. Finally, Section 4.5 discusses and compares our results with previous sections.

4.1. Study Settings

We created three groups to investigate whether the use of online learning features contribute to improve student exam grades. Table 1 shows the three groups with the UML content covered during the course and how this content is made available to each group. Group A had only face-to-face classes; that is, with no online support. Group B had face-to-face classes and video lectures. Group C had face-to-face classes, video lectures, and online questionnaires. Additionally, it can be said that our study covers three consecutive years (2012, 2013, and 2014) and each group is composed by students from two different semesters of the same year. Therefore, Groups A, B, and C are composed by students from the first and second semester of 2012, 2013, and 2014, respectively. The number of students per semester and the total number of students can also be seen at the end of Table 1. For instance, Group A had 48 students in 2012-1 and 34 students in 2012-2, summing up to 82 students in 2012.

Table 1. The UML Content and the number of Students for each Group

UML Content	Group A	Group B	Group C
Introduction to UML	C1	C1,V1	C1,V1,Q1
Introduction to the main UML Diagrams	C2	C2,V2	C2,V2,Q1
Use Case Diagram	C2	C2,V3	C2,V3,Q1
Class Diagram	C3	C3,V4	C3,V4,Q2
Sequence Diagram	C3	C3,V5	C3,V5,Q2
Communication Diagram	C4	C4,V6	C4,V6,Q3
Activities Diagram	C4	C4,V7	C4,V7,Q3
Total students per semester	**48+34**	**37+22**	**20+32**
Total students per year	**82**	**59**	**52**

Considering all students from the three groups, we analyzed data from 193 students. These data were taken in the end of the semester and, only questions and lectures related to UML were analyzed in this paper. The same instructor was responsible by all face-to-face classes. It is also important to say that online questionnaires are not equal to any exam questions. The UML content described in Table 1 was divided into four regular classes (C1, C2, C3, and C4), seven different video lectures (from V1 to V7), and three online questionnaires (Q1, Q2, and Q3).

4.2. Students Performance per Year

Figure 2 shows the average performance of students on exam questions in each semester. In 2012-1, the students got on an average grade of 55% and in 2012-2 they got an average of 64%, resulting in an average of 59% in 2012 (Group A). For Group B, the average of grades obtained was 52%. There was an intriguing low average grade in 2013-2: 35% (discussed below). Finally, for Group C, it was found an average of 80% and 78% for the semesters 2014-1 and 2014-2, resulting in an average of 79% for this group.

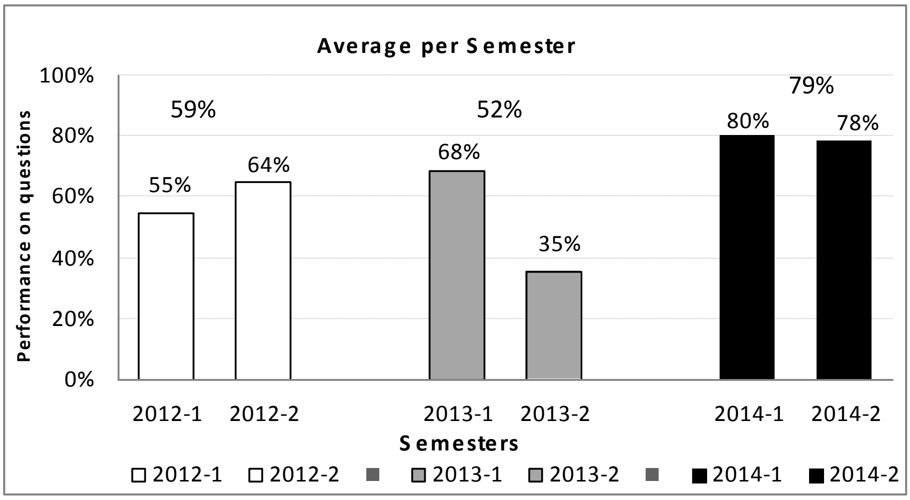

Figure 2. Student performance in questions relating to UML per Semester

Table 2 shows the number of exam questions applied per semester. A column with a percentage value means that the specific questions (represented by each line) appear in the corresponding semester. For instance, Questions 1 and 2 were included in the exams of 2012-2 and the average grade of the enrolled students was 73% and 56% for these questions, respectively. The unusual result in 2013-2 (see Figure 2) is probably due to the fact that only one question about UML was applied to students in this semester. After inspecting the 2013-2 exams, we observed that this UML question has a higher level of difficulty.

It is not trivial to measure how difficulty a question is, but note that the lowest average grades per semester occurred in 2012-1 and 2013-2 (Figure 2). In both semesters, exams had only one UML-related question. In spite of that, grades in 2012-1 were better than 2013-2. Additionally, we can note that Question 4 appeared also in 2014-1 and, despite students get an average of 54% in this question (20% higher than in 2013-2), this average is the lowest in the 2014-1. Therefore, we can conclude that Question 4 was more difficult than other UML questions. The last affirmation is also supported by Figure 2. Note that, the average grades in 2014-1 was 80%, yet the average grade for Question 4 was only 54%.

Table 2. UML questions applied in exams and total questions in each semester

Question	2012-1	2012-2	2013-1	2013-2	2014-1	2014-2
Question 1		73%	81%		92%	90%
Question 2		56%	57%		76%	75%
Question 3			83%		90%	
Question 4				35%	54%	
Question 5			52%			
Question 6					86%	
Question 7						74%
Question 8	55%					
Total Questions	**1**	**2**	**4**	**1**	**5**	**3**

By analyzing the different features of online support and still based on the results presented in Figure 2, it is clear that online questionnaires (Group C) help students to improve the exam grades. The improvement of Group C with respect to Groups A and B is an average of 20% and 27%, respectively. Related to support of video lectures, it is not clear an increased in student exam grades. On the contrary, we can observe a decreased of 7% in average grades from Group A to Group B. As previously discussed, this decrease can be due to uncontrolled confounding factors, such the difficulty of exam questions.

4.3. Analysis of Performance in Two Recurring Questions

In the previous analysis (Section 4.2), we said that it is hard to measure the difficulty of exam questions. To mitigate this threat, we compared only questions which repeat in more than 3 semesters. Therefore, this section evaluates the support of online content in two specific questions (1 and 2). These questions repeated in four semesters (2012-2, 2013-1, 2014-1, and 2014-2). Hence, these questions were applied in at least one semester of all analyzed groups.

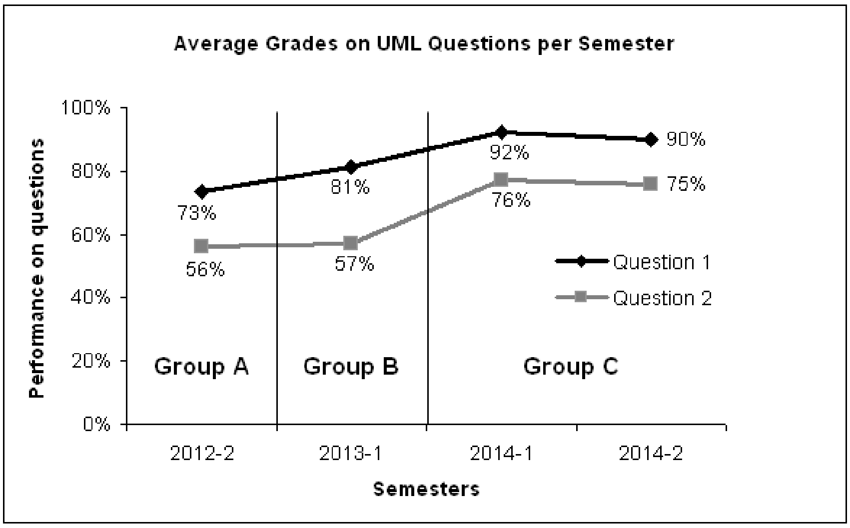

Figure 3. Average grades on two UML questions between semesters

Figure 3 shows that, for both Questions 1 and 2, there is an improvement in exam grades in semesters with some online support (since 2013-1). Exam grades had an improvement of 8% in average for Question 1 from Group B to Group A. Similarly, an improvement of 19% in exam grades can be observed from Group C to Group A. With respect to Question 2, there is an improvement of 20% and 21 % in student grades of Group C compared to Groups B and A, respectively. These results show that online support have a positive impact in both levels (video lectures and online questionnaires). However, online questionnaires is mostly responsible for the improvement in the average exam grades of students.

4.4. Correlating Presence in Face-to-Face Classes with Exam Grades

We verified and analyzed the correlation (using Pearson coefficient) between the presence of students in face-to-face UML classes and exam grades considering only UML-related questions. Pearson Coefficient vary from -1 to 1, where -1 means a perfect negative correlation and 1 means a perfect positive correlation. Values close to 0 represents no linear correlation. With this analysis, we aim to see if online support is enough to teach students. In other words, considering Group A, if presence has a high positive correlation with student's exam grades it means that face-to-face classes are important to learn UML content. On the other hand, if the presence has non-correlation (close to 0) with student exam grades, it means that presence is not an important factor to learn UML content.

Table 3 shows the results of the correlation of presence in face-to-face classes and the student exam grades for all six semester considered in this study. For Group A, we obtained correlation values of 0.17 and 0.23 in 2012-1 and 2012-2, respectively. For Group B, we obtained 0.32 for 2013-1 and 0.45 for 2013-2. Finally, for Group C, we obtained correlation values of 0.65 and 0.60 for 2014-1 and 2014-2, respectively. The Pearson coefficient values were increasing from Group A to Group C. For Groups A and B, we considered a low correlation, close to no linear correlation (smaller than 0.5). These results suggest that face-to-face classes, regardless of video lectures, do not strongly support students to learn UML.

In the case of Group C, there is a moderate correlation between the presence of students in face-to-face and their exam grades. It is hard to explain such increase in the correlation. We believe that these results are related to how mature the online course becomes. That is, the online course in 2014 includes both video lectures and online questionnaires. As a result, students may have neglected face-to-face classes in favor of online video lectures and questionnaires. However, students who regularly attended face-to-face classes better learned UML than the ones who only relied on online content. As a general conclusion, we may say that face-to-face classes alone is not enough to support UML learning (Groups A and B), but student who skip these lectures cannot learn UML only based on online content (Group C).

Table 3. Correlation between presence in face-to-face classes and grades in exams

Semester	**2012-1**	**2012-2**	**2013-1**	**2013-2**	**2014-1**	**2014-2**
Correlation	0.17	0.23	0.32	0.45	0.65	0.60

4.5. Discussion

Observing the performance of students per year versus their performance for recurring questions, we note that the video lectures contributed to improving the exam grades of students in the analyzed questions. Certainly, there were questions with a high degree of difficulty that even with online content available, students could not obtain good performance, as explained in Section 4.2. According to Figure 3, we can clearly see that for Question 1, there was an increase in performance of the Groups B and C compared to Group A. For Question 2, we see a small improvement from Group A to Group B, but it is not so clear. These two analyses lead us to conclude that student performance can be related to the type of question. In all analyzes, we have an improvement in the performance of Group C. Therefore, we conclude the online questionnaires in general support UML learning.

The clear improvement of online questionnaires and the questionable improvement of video lectures in UML learning probably are justified by the fact that students have an extra opportunity to practice their knowledge acquired in the face-to-face classes when they are doing the online questionnaires. They probably revisit other UML content and sources of information to resolve the questionnaires. This behavior contributes for an improvement in learning, because we are assuming that students who perform questionnaires and watches the video lectures spent more time studying than the ones who only attends face-to-face classes. Online questionnaires available in online learning environment are considered for evaluation. Hence, students earn points when they complete the questions, and this fact can motivate students to access the online platform and carry out the online activities. On the other hand, when only the video lectures are available, the students do not seem motivated because the access to video lectures does not count for their grades.

With our analysis of correlation, we can see that face-to-face classes are not so important to increase the exam grades of student in regular classes. This probably happen because in addition to online course, there are several sources of UML information, such as books, websites, and other online content. Therefore, students may consult other sources of information. We believe that other ways of teaching UML should be investigated, such as learn-by-doing and educational games. That is, face-to-face classes are important, but since UML is a visual content, it requires additional effort from the instructor to be taught.

The findings of our previous work [Pereira et al., 2013; Figueiredo et al., 2014; Garcia et al., 2014] has shown that the performance in online questionnaires have low or moderate correlation with performance in exams. In this paper, we are evaluating if the use of online activities, focusing on video lectures and online questionnaires, contribute to the increase of exam grades of students in UML content. Our results confirm that video lectures and online questionnaires available to students help to improve the UML learning. Previous work also shows that the error rate in online questionnaires is almost the same in more than one semester. In our study, exam questions with the highest error rate also occurred in more than one semester. This result suggests that students have similar profile and a difficult question for students in one semester probably also is difficult for students in other semesters.

5. Threats to Validity

Even with careful planning, this research can be affected by factors that could not be fully controlled, and may invalidate its main conclusions. Actions to mitigate their impact on the research results are described as follows.

The evolution of the course dynamics and students who failed. The evolution of the course dynamics can impact on the results. For example, changes in the order in which the contents are covered. In our work, the instructor followed the same general order of teaching in all semesters analyzed. Students who previously failed and attend the course a second time can also impact on the results because they may increase their exam notes. That is, these students already know the discipline and some exam questions. However, this threat is minimized because the course failure rate is of only 10% to 20%, and less than 5% of students in a class have attended it before.

The number of students assessed and exam questions for each semester. We consider that the number of students assessed in each semester is a minor threat because each class has 20 or more students and an average of 32 students per semester. Hence, in a class with 20 students, one or two high grades or low grades do not cause a big impact on the class average. The number of UML-related questions in exams is different between the semesters analyzed. However, some questions repeated in more than one semester allowing us mitigate the impact of question difficulty.

Online environment and student backgrounds. Online activities are not in a fully controlled environment. In other words, we cannot control whether students answer the questionnaires in groups or alone, or whether they cheat. However, we did not assess the impact of scores in online questionnaires on the UML learning. In fact, we are evaluating whether using online activities along with regular classes helps to improve UML learning (measured by grades in face-to-face exams). In addition, students are instructed to first attend the regular classes before accessing online content. The background of students is not controlled in this study, but empirical evidences show that students have similar average background knowledge over the years.

Scope limitation and threat to cause and effect - Our results are restricted to students from UFMG and only for UML content in a specific Software Engineering course. We cannot generalize our results to other universities, but students of the same course tend to have similar profiles. Related to threat to cause and effect, there is the possibility of actually students' knowledge had impact the results of the exams, and not because they answered an online questionnaire. That is, good students can solve the exams without difficulty because they are good students, and not because they solved questionnaires. This way, it is clearly hard to identify what action generates the actual effect on the other.

6. Conclusions and Future Work

This study evaluates whether online activities, such as video lectures and online questionnaires, contribute to improve student exam grades. We assessed the grades of 193 students of 6 different semesters and divided them into three groups that had different types of online support, but with the same UML content. The first group had only face-to-face classes, the second group had face-to-face and video lectures and, the third group had face-to-face classes, video lectures, and online questionnaires. The online content is available in the Udemy platform for a Software Engineering course [Pereira et al., 2013].

Two main analyses were performed. First, we analyzed the student grades per semester and, then, we analyze the student grades for the same two questions in four semesters. Based on the results of this work, we conclude that the use of a platform to provide online content contributes to improving exam grades in questions related to UML. For the third group, that had access to online questionnaires and video lectures, the difference of student grades were about 20% compared to students that did not have access to online content.

Moreover, for two exam questions that repeated over four semesters, the grades increased by up to 20% for students who had access to video lectures and online questionnaires, compared with students who did not have access to online support. In the analysis per year, students who accessed only video lectures (Group B) had minor improvement in performance (1% to 8%) compared to the group who did not access any online content (Group A). On the other hand, students who accessed only video lectures (Group B) had a performance significantly lower (more than 10%) than students who accessed videos and online questionnaires (Group C). However, according to the analysis of repeated questions (Section 4.3), the use of video lectures contributes to increase of grades depending on the type of question. In general, this result shows that the use of other sources of study, such as video lectures and online questionnaires, help students as they study for a longer period of time than just in regular classes.

Our results also suggest that students perform better when exams have more than one question related to the same topic (UML, in our case). This fact helps students that know some specific content because with more questions they have more chance to answer one question related to a specific content they know. We believe that when the students have to do one activity in the online platform (such as questionnaires), the chance to access other content, such as video lectures, is higher than when they have only video lectures. Probably, they do not access the platform when they have only the video lectures, such as in the year of 2013. On the other hand, when online questions are available, students accessed the platform.

For future work, it is interesting to analyze online questionnaires in the context of online educational games and if games contribute to student learning of UML-related content. We also aim to further analysis whether other topics of Software Engineering can be supported from the use of online learning platforms. Furthermore, we can correlate other learning units, such as the performance in online questionnaires with performance on exam questions related to UML content.

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