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E-Learning And Assessment in the Cloud: Engineering Courses

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E-Learning And Assessment in the Cloud: Engineering Courses

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Abstract

Modern technology allows educational systems to facilitate novel feedback approaches between students and teachers. Various tools and approaches have emerged in the recent years with various levels of documented success in student learning. Consequently, it has become widespread that classroom teaching may be assisted by distance learning technologies (eg. web tools), especially with respect to reducing the intense reliance on in-class teaching and manually supervised grading. In addition, similar to other aspects of societal development, educational technology innovations that pass the test of time, have the feature of being constantly updated and archived. In particular, intense updating and maintenance are required not only in the educational front format that students and instructors see, but also in the capacity and speed of Cloud storage functions that may be relevant and accessible for multiple student generations. In this context, a major tool that has the potential of becoming indispensable is the Google Suite for Education. We report on an evidence-based practice study that has been carried out in the Engineering course for Juniors, Introduction to Thermodynamics, to assess the effectiveness of the E-Learning environment Google-Classroom into facilitating classroom teaching and enriching traditional instruction methods. We discuss diverse ways of leveraging such technology in the classroom, its benefits, but also possible concerns in the implementation if not well thought out. In this paper, we focus on the use of an integrated online homework delivery system based upon the Google online ecosystem, an integrated online delivery system for weekly quizzes that follow the formats and guidelines of the Fundamentals of Engineering (FE) national examination for professional engineers, as well as an integrated system of virtual lectures and office hours. Student performance was tracked weekly for 12 weeks throughout one semester. We present, statistics and comparisons, week after week, from student grades in administered quizzes, homeworks, as well as student assessment and overall insights from the pilot use of this framework towards improvements in other inter-disciplinary, large-audience courses in engineering classrooms. We find that the semester-long student performance in FE-like quizzes was strongly correlated to the final exam grade percentage and also, the final grade percentage. We also find that a spurious peak in the statistical histograms was associated to student integrity issues that were effectively and efficiently mitigated in subsequent quizzes. The framework's versatility allows students to be constantly aware of their performance regarding learning objectives, while at the same time, it helps them identify areas that require more attention. Also, the instructor has a new level of control over the course, its grading and feedback, as well as innovative approaches to preserving academic integrity. These features make this online-assisted educational framework an effective educational tool for learning in both large classrooms and online courses, where students may reach a new level of learning and understanding.

Introduction

A critical aspect of education is its vital connection to tradition. For example, in typical college engineering courses such as statics, dynamics and thermodynamics, all the concepts, ideas and devices were invented and described in detail more than a century before. *Traditional classrooms* characterized by a lecture and blackboard interaction with students have remained a stronghold in engineering courses, available to multiple engineering departments, primarily due to the closest generational connection of the education style. Traditional classroom experiences may be limited to the audiovisual interaction with the instructor and the blackboard and may be enriched by modern technology-enabled classrooms that can deliver impressive intensity of knowledge transfer through the use of various audio-visual tools, while seamlessly incorporating active learning techniques [1,2]. In this paper, we focus on an evidence-based practice study that has been carried out in an Engineering course for Juniors, Introduction to Thermodynamics (see Figure 1), to assess the effectiveness of the technology-enabling (E-Learning) environment labeled as Google-Classroom (GC), into enriching classroom teaching. We show ways to use an integrated online homework delivery system based upon the Google online ecosystem, an integrated online delivery system for weekly quizzes that follow the formats and guidelines of the Fundamentals of Engineering (FE) national examination for professional engineers, as well as an integrated system of virtual lectures and office hours. We present the evidence-based practice data we collected in the distinct aspects of the homework delivery system, the FE exam delivery and student assessment, the virtual lectures and office hours, and finally the archival ability of GC. Finally, we conclude with remarks and possible future directions in teaching innovation research.

Background

Through technology, a teacher may clarify doubts related to a particular topic quickly, giving real-world video examples. Students may absorb concepts taught over a period of time, like in any learning experience, but with more input and more intense technology-controlled feedback. This capacity to deliver more information and feedback in a swift, flexible manner that may have led to the significant increase of curriculum contents in engineering colleges across the world, maintaining a much closer pace with up-to-date industry standards and requirements. Given the historical importance of traditional education strategies, the key role of emerging technologies typically is to assist and facilitate traditional classrooms instead of replacing them. *E-Learning* [3], a modern buzzword, encapsulates all such technology tools that reshape the traditional classroom learning experience.

A key aspect of E-learning that functions in its very background is *Cloud Computing* [4]: Storing and accessing data and software programs over the internet instead of local computers' hard drives. This under-appreciated aspect of education, cloud computing, forms the base for E-Learning wherein the teacher develops material and assignments [5], keeps track of student performance and records [6]; At the same time, *cloud computing* allows students to collaborate from the comfort zone of the device and location of their choice, as well as experience learning in a somewhat autonomous and creative way [7], while pursuing learning at their own personal pace. However, a major setback of cloud computing is the cost of storing information that may increase dramatically with the storage increase, while the speed of access may not only depend on wireless systems but also depend on the particular cloud provider utilized. The *speed of access* is the most important aspect that both students and instuctors value in E-learning, since otherwise making a local copy to a device becomes more efficient. While these comments may seem redundant and possibly obsolete in a quickly developing technology, they acquire serious substance when they are considered in the context of traditional educational experiences, where the leading E-learning providers (McGraw Hill, etc.) are focused more on the educational material and not so much on the cloud computing developments. It is important to note that Cloud Computing strategies in educational institutes are keys for innovation and realization of the true potential of techniques such as web services, virtualization and grid computing [5]. The relevance of Cloud Computing becomes increasingly important as it is expected to offer flexibility and pay as you go cost structure.

There is a large collection of E-Learning tools available [8], especially for college engineering courses related to fundamental concepts such as statics, dynamics, mechanics of materials, thermodynamics. In an accord with market rules, for every engineering course that is available and mandatory in the curriculum requirements of a multitude of engineering disciplines, there is a large number of possible E-learning options. In this context, the Google Suite stands as a generic tool for cloud computing that facilitates collaboration across teams of any type, using tools such as Drive, Gmail and Gdocs, Forms, Sheets and Slides [9,10,11,12]. In this context, the Google Education component, through the Google Classroom tool, provides a collaborative solution for both the teacher and her/his students [10, 11]. A teacher may create a Google Classroom (GC) for any particular subject by adding all the students belonging to that class through their email addresses, and then add material through the use of Google Suite tools. In this work, we present an evidence-based practice of the Google Classroom tool in an Engineering Course on the Juniors' course "Introduction to Thermodynamics", with 76 students from 5 engineering disciplines (see Figure 1).

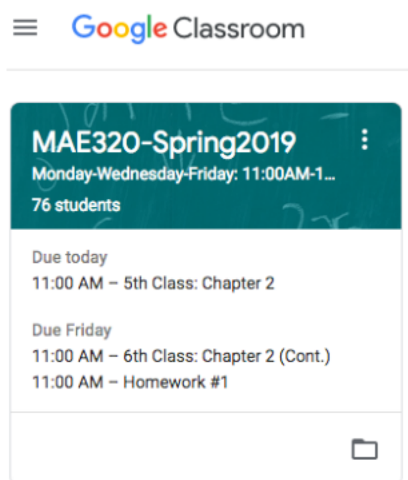

Figure 1:The Google Classroom front page for the administered course, discussed in this work, available through the Google eco-system.

Google Classroom has a large variety of benefits that are common across E-learning tools. Multiple instructors may be added in the system so that students may gain additional material and ideas on the same topic from multiple teachers. Reference material may be delivered to students well in advance of the traditional classroom experience, so that students may come well prepared for the topic and promote interaction in the overall learning process. Students get email notifications for every new assignment or/and material posted in the GC, as well as notifications in devices (phones) where the same Google Classroom app is installed. Such notifications may include posting announcements, assignments, homework/quiz/lecture material, student questions related to any particular topic, as well as new discussions initiated by either students or instructors. Naturally, Google Classroom fits well into the category of flipped classrooms which are becoming increasingly popular [13]: Namely, instructional material may be introduced much before class in pre-assigned times and the traditional classroom time is being used to deepen understanding through discussion with peers and problem-solving activities facilitated by the instructor. Nevertheless, despite these benefits, GCs have been virtually absent in the author's institution (West Virginia University) as well as most US institutions, mainly due to the *minimal* character of document editing capabilities (*e.g.* a subscript/superscript of an equation may only be implemented through an image in a Forms-administered quiz), and the dominance of traditional publishers in introducing excellent but expensive (to the students or institutions) E-learning tools [14]. Despite plausible caveats and question marks related to popular engineering books and tools [15], E-learning tools such as GC have an immense value, that goes way beyond than meets the eye for its state-of-art speed, free character across most US institutions, and characteristic easiness for customization that can be adopted through a variety of courses, independently of the level (*e.g.* undergraduate/graduate).

The Google Suite has become a focus topic across education practitioners. Railean [16] provides an overview of the capabilities provided by Google Apps while covering theory and practical aspects of the tools and their advantages for the development of skillsets. In [17], a usability study was introduced, that examines the perception of student groups and the GC community, assessing the importance of GC tools. In general, students identify the Google Suite as quite easy to use, while its cost of usage remains minimal [18]. In addition, research studies have been conducted to gauge the perception of university professors towards virtual classroom technologies and the results show that the professors are in favor of integrating Google Apps into their instructional strategies provided they are equipped with appropriate professional development and training [19, 20]. A key, exceptional feature of GC is its seamless integration in the fast-access Google cloud computing. The importance of cloud computing for training purposes has been noticed by various authors. An example is discussed in [14], where the usage of network technology to deliver training is described as the revolution in the field of E-Learning, taking a practitioners' approach to assess E-Learning, and looking into the possible drawbacks and challenges in this field. Indeed, it appears that understanding how learning is realized in online environments may also fix significant issues associated with the integration of internet into the students' lives.

In this paper, we focus on the implementation of the Google Suite for Education to a set of 76 university Junior students of a single section of the course "Introduction to Thermodynamics for Engineers", servicing six engineering departments (Mechanical, Aerospace, Chemical, Environmental, Industrial, Petroleum), that follows a popular engineering book (Cengel&Boles) up to its 7th chapter [15]. The course was administered at the West Virginia University(WVU)'s Statler School of Engineering and Mineral Resources. WVU offers the Google Suite to all its students and employees free of charge and with infinite storage capacity, similarly to other public institutions in the U.S. and abroad (*e.g.* U. Groningen, Netherlands or Colorado State University [9]). The usage of freely available Google Apps for collaboration in a public institution (Colorado State University) and the multiple advantages for all the university stakeholders, have been well documented [9]. We report on an evidence-based practice study that has been carried out in the Engineering course for Juniors, Introduction to Thermodynamics, to assess the effectiveness of the E-Learning environment Google-Classroom into facilitating classroom teaching. We discuss diverse ways of leveraging such technology in the classroom, its benefits, but also possible concerns in the implementation if not well thought out. In this paper, we focus on presenting the ways to use an integrated online homework delivery system based upon the Google online ecosystem, an integrated online delivery system for weekly quizzes that follow the formats and guidelines of the Fundamentals of Engineering (FE) national examination for professional engineers [21], as well as an integrated system of virtual lectures and office hours. Student performance was tracked weekly for 12 weeks throughout one semester. In the following, we discuss the evidence-based practice data we collected in the distinct aspects of the homework delivery system, the FE exam delivery and student assessment, the virtual lectures and office hours, and finally the archival ability of GC. The data collection was based on common performance indicators in the course, such as grades for homeworks, quizzes and exams. The data analysis was performed through typical statistical measures, in analogy to prior studies [17]. Ultimately, we present our concluding remarks and possible future directions in teaching innovation research.

Homework Delivery System

Assessments are an integral form of the education system and even more in engineering education, where education has a strong element of *knowledge translation:* transitioning from the book knowledge to device and tool development in the industry. The core element of assessments are assignments that aim at gauging learning at various periods during the time the course is taught. However, current educational systems rely heavily on professor-student feedback and manual supervised grading. This fact can cause mistrust and validation issues due to, for example, delayed return of assignments (e.g., tests and homework), difficulty in grading, incomplete justification of grades, and inadequate student feedback. As a result, students have limited time to review the proper solution of the assignments and to learn from mistakes. In addition, course improvement for subsequent semesters becomes cumbersome, due to limited time/information available. In the evidence-based practice, we studied the effect of 10 homework sets, consisting of 5-7 problems with both numerical and multiple-choice questions, fully administered online, handed over to students through Google Classroom, and using each time a Google Form that could be edited after being submitted. The homework set acceptance was stopped at a pre-specified deadline (a week after the homework announcement). All announcements were scheduled automatically in the beginning of the semester, updating both students' personal Google Calendars and also through emails. Homework assignments were graded semi-automatically, by using the Sheets' add-on package Flubaroo. Flubaroo allows for grading both numerical, with margins, questions and multiple-choice ones. Moreover, Flubaroo is a post-processing element on homework solutions, which implies that students shall not mis-graded: By visual inspection of all student answers, Google Forms and Sheets allow the instructor to see strong correlations among answers -- if the instructor-designated answer is too far from common student answers, then Flubaroo will automatically detect it as a very low-performing answer, and color the designated answer, effectively urging the instructor to revisit the homework solution set. This feature is a great necessity for preserving the trust bond between the instructor and students on solutions' and presented material correctness. Another aspect of impressive effectiveness is the ability of providing automatic feedback to each student according to whether his/her answer was correct or incorrect. For every homework assignment, the students received personalized feedback automatically both at the expiration deadline, as well as together with their homework grades. Applying E-Learning for grading [14], evaluation and feedback, as opposed to the traditional manual way of submitting assignments, provide a wealth of versatile tools towards the analysis of student performance. During this evidence-based practice study, Sheets were used for *every* homework assignment to produce a histogram of homework performance across the 70 students, and students were notified of peer performance (see Figure 2 for an example). Informing students on peer performance allows them to be self-aware of their position in the class and their learning ability compared to the average behavior (ultimately influencing their final letter grade). The framework's versatility allowed students to be constantly aware of their performance regarding learning objectives, while at the same time, it helps them identify areas that require

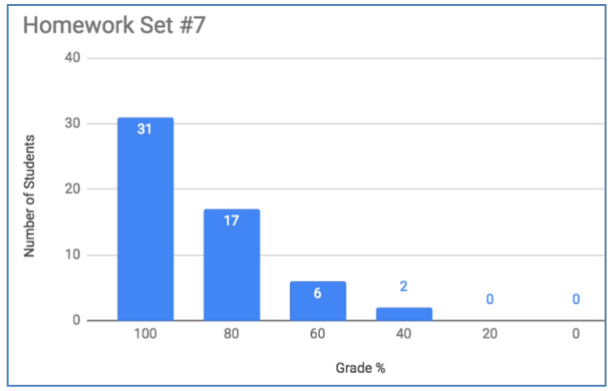

Figure 2: Histogram Produced for Grades of Homework Set

more attention. Also, the instructor now had a new level of control over the course, its grading and feedback, as well as innovative approaches to preserving academic integrity. These features certainly promote this online-assisted educational framework into an effective educational tool for learning in both large classrooms and online courses, where students may reach a new level of learning and understanding.

The ability to observe peer performance histograms allowed to identify a group of students that were evidently mis-handling their assignments over academic integrity issues, in the middle of the semester. This kind of academic integrity issues are extremely widespread across online courses, given that students may copy/paste material in the web's search engines very swiftly. In this case, student performance histograms formed a statistically improbable peak in the histogram, and then several solutions were implemented: i) make sure *a priori* that homework questions are not identifiable in common web search engines, ii) include special symbols in the questions that make them untraceable by web search engines, iii) upload homework questions as images, so that relevant text cannot be copied/pasted in a swift manner. Nevertheless, an instructor needs to be extra careful when using online tools, such as GC, for administering homeworks and exams throughout a semester.

FE Exam Delivery System

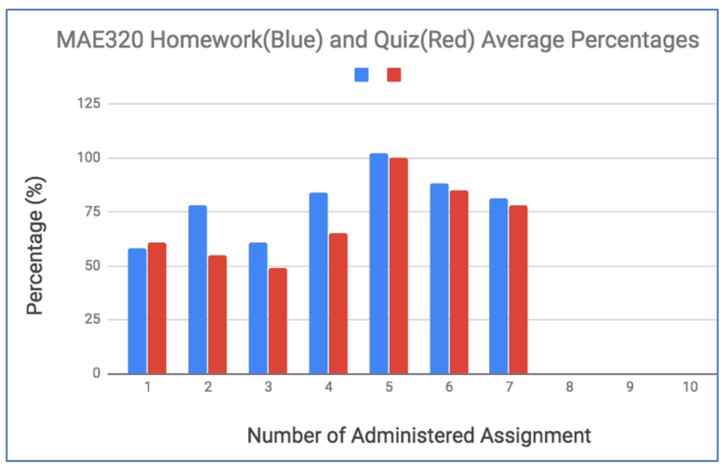

Figure 3: Averages of Histograms Produced for Grades of Homework Sets and Quizzes up to middle of Spring semester

The standard Fundamentals of Engineering U.S. National Examination is typically considered as an outcomes assessment tools for various accreditation procedures, such as the one delivered by the Accreditation Board for Engineering and Technology (ABET). ABET is a non-profit accrediting agency for academic programs in applied and natural sciences, as well as engineering and technology disciplines, providing assurance that the profession's high standards in student preparation are met. A major portion of the overall program assessment is a compilation of student outcomes, reflecting the skills and attributes that all Mechanical Engineering students are expected to possess at the time of graduation. These student outcomes are based on documentation collected during the annual assessment process and represent a combination of direct and indirect measures, such as the performance of student work, FE exam results, formal survey data, as well as data of specific curriculum courses' completion. The course of Thermodynamics represents a significant portion of the FE exam (~10%). In this evidence-based practice study, students were tested weekly under the FE exam format (3 minutes per question, 4-5 questions) in a pre-set time interval. The exams were administered through Google Classroom and Google Forms, and students used their phone to access the tested questions and answer the FE-quiz, in the beginning of the class. The primary advantage of the approach was its immense versatility in informing and testing students, as well as giving them feedback, immediately after the FE-quiz exam. Histograms of FE exam performance results were tracked throughout the semester in a very swift approach, by using Google Sheets through seamless data transfers. A collection of homework and exam average performances (where the top performance was set at 100%) is shown in Figure 3 up to homework/FE-exam 7. Through this simple graph, one may notice a correlation between homework and quiz performances, that may demonstrate that the homeworks were successful in promoting learning that could become useful in exam questions. Nevertheless, it is worth noting that it is also possible that the correlation may signify the varying level of difficulty of the material studied.

In addition, one may observe an "abnormal" peak at 100% at both homeworks and FE exams, a moment that triggered the instructor's suspicion towards identifying an academic integrity issue, by noticing that students were copying/pasting the questions' text into a web browser and looked for answers in online websites, during the exams. Naturally, the versatile character of Google Classroom allowed for a swift solution to be identified that virtually solved the problem: Questions were screen-shotted before being uploaded at a Google Form, thus preventing students from being able to copy/paste anything significant. The summary of this evidence-based practice study is that Google Classroom allowed for the clear identification and solution of problems that are possibly ongoing throughout the education system undetected. It is natural to expect that this class will outperform the departmental averages in the FE exam, when they attempt to take it in 2 years or so. However, such an investigation is beyond the purposes of the current evidence-based practice study.

Virtual Lectures and Office Hours

In the long term, Google Classroom can become an indispensable tool for the instructor of large audiences. The aspect of pre-planning a classroom in the beginning of a semester to appear in a pre-designed schedule, can become so automated that can hold both instructor and students accountable on identical footings and also, it is especially useful for combined research/teaching (tenure-track) faculty that need to align their schedule with multiple research, teaching and professional/university service responsibilities. In addition, online homeworks and FE quizzes emphasize engineering problem solving ability instead of literature memory aspects in a way that can be statistically tracked for multiple generations of students. The statistical tracking can be performed in a seamless manner, generating histograms of performance and participation (see Figures 2, 3), which may even be used to detect and resolve mis-handling effects in the classroom. Ultimately, though, the most important aspect of such a framework is the ability to transform a large, nameless, audience of 70+ students, into an intense instructor-student personal exchange that is a typical benefit of small audiences (<30 students). In this evidence-based practice study, the homework and FE quiz exam feedbacks emphasized multi-level learning, where students were receiving email feedback immediately after submitting their solutions, online feedback when their solutions were graded, and finally online feedback when solutions were posted online. All these feedbacks were personalized in the sense that there was a constant reference and URL links to the individual student's solution which was stored on the Google Drive. The overall effect on students, as unveiled from several private acknowledgement letters to the instructor at the end of the semester, was the feeling of being comfortable with accessing information and reaching the instructor for feedback. This level of comfortable feeling even allowed for performing virtual lectures in several occasions throughout the semester of this evidence-based practice study, administered through Google Hangouts and recorded for future use.

Finally, virtual office hours, administered through the Google Meet, allowed for comments, questions, and answers being accessible by all students, during or after the office hours, while the instructor did not need to be in office during these hours. It was finally observed that the ability to have virtual office hours in a directly and easily accessible manner, becomes radically more important during exam weeks, where students need much more feedback, both from the instructor and peer students.

Archival Ability of Google Suite

Current educational systems rely heavily on the experience of the instructor in handling and modifying aspects of the curriculum and the way a course is taught in the classroom. Essentially, the memory and experience of an instructor throughout his/her education path defines the rate of progress in teaching innovation. As a result, course improvement for subsequent semesters becomes cumbersome, due to the absence of additional tools that can efficiently gauge the performance and education outcomes [21]. It is clear that various online educational approaches have been advanced in various institutions, including WVU (*e.g.* MasteringEngineering *etc*.), however it is a common caveat that these systems' archival ability is hampered by the naturally rigid software/cloud structure and the non-optimal nature of the cloud technologies used. Grading generations of students, storing and sorting the performances of students from previous years, having a library of questions that is easily accessible, and containing academic integrity value, are all tasks that require state-of-art technologies that are a natural asset of Google's technological excellence. In this way, the very simple graph of correlating FE quiz averages with final grade average across exams and homeworks (Figure 4) has been stored in the Spring 2019 folder and is directly accessible and comparable for future generations. The slope/trend of the correlation (solid lines in Figure 4) represent signatures of the FE-quiz effectiveness (being only 10% of the final grade sum) in mediating learning skills, that can translate into exam performance. It is worth pointing out that the correlation of the fits in Figure 4 persists even if 3 outliers are removed from the fitting regime in each of the graphs. Thus, a natural benefit of such archival ability is the capacity of instructors to gauge the relative effectiveness of novel teaching techniques into producing more effectiveness in the targeted educational outcomes. Finally, the

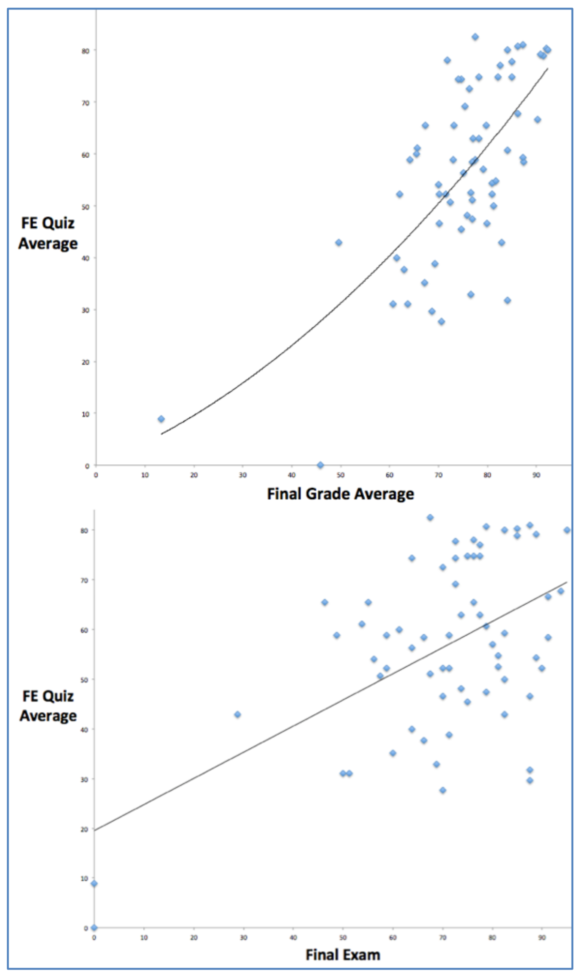

Figure 4: Correlation between FE quiz grades and Final Exam performance and overall final grade. The lines represent fits that are also guides to the eye. The correlation of the fit persists in the absence of 3 outlier points at the lower left of each graph.

instructor has a unique capacity to compare classes, and identify excelling individual students that can be especially promoted into academic job search fairs through insightful and data-supported recommendation letters.

Limitations

The effects and improvements for classroom teaching, induced by the use of the online software Google Classroom, are evident, similar to the effects of the associated software freely available in the Google Suite (eg. Sheets, Docs, Forms, Slides). Nevertheless, the whole framework, as it was implemented in this evidence-based practice study, contains two major limitations: First, the use of cell phones is naturally intense and causes distraction feelings. Through this evidence-based practice, students were constantly requested to use their cell phone to access documents. Second, the software is akin to its popular cousins, causing degeneracy feelings. Google-based software has numerous uses outside of classrooms, leading to a feeling among students that it is a "Google search" software. Especially, in the cases of students that pay large tuition fees, it is expected that dedicated software should become available with each and every class. It is clear that Google Classroom is a very powerful software for classrooms that require/need free software that may provide fast, online solutions for assignment / lecture delivery and archival storage.

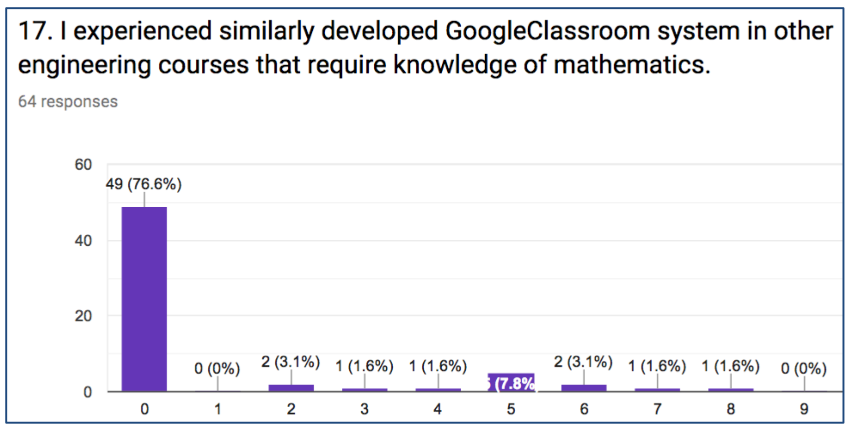

Figure 5: Sample Histogram of Answers on Class Assessment Quiz before first mid-term exam

Conclusions/Future Directions

This work proposed the use of an integrated online homework delivery system that is focused on the Google Classroom framework, which is free and naturally available in most US institutions. While other online frameworks can equally perform for education purposes, Google Classroom stands out in the capacity of providing freely available resources, translational ability across educational functions, and archival character across student generations, Through the use of the full potential of this educational framework, it is proposed that online-assisted classroom education can be effective, statistically testable and can help address most of the concerns that emerge in the teaching of engineering courses that service multiple engineering departments. An evidence-based practice study of the integrated Google Classroom framework was demonstrated that allows students, previously unaware of the Google Classroom framework (see Figure 5), to be constantly aware of their performance regarding learning objectives, while at the same time, it helps them identify areas requiring attention. The system was tested on a 76-student section of the course of Mechanical Engineering: Introduction to Thermodynamics, a pilot application of the proposed educational framework in a main course for Engineering Juniors. Several students

(14) sent private letters to the instructor after the end of the semester, acknowledging that they felt comfortable and organized by using Google Classroom, and recognized a significant acceleration of their learning process. In this course, statistics and comparisons were produced, week after week, for administered FE-exam quizzes and homeworks. Student assessments were presented and insights from the pilot use of this framework were discussed. The main advantages of the framework were the automatically graded homeworks and FE quizzes that are quickly and customly-designed by the instructor and may provide real-time feedback for both students and instructors. This framework gave the instructor a new level of control over the course, by accessing information the students submit and easily identify both areas that students are performing well and areas that students seem to be lacking understanding. A key feature of the framework was the ability it provides to easily modify and improve the version of the homework being used. Finally, the fact that the framework is free and integrated to other typical student activities (Gmail, Gcalendar) make it ideal for educational purposes, especially at WVU that uses Google to provide emailing and archival access to students across the WVU campus and alumni. These features make this online-assisted educational framework an effective educational tool for learning in large audiences and online courses, with students being able to reach a new level of learning, understanding through statistical information access. In the future, it is expected that the implementation will prioritize the realization of full capacity to promote distance learning in this and other engineering courses, by including videos for all lectures. Through this way, in the presence of in-person classroom teaching, this system will realize a seamless implementation of a flipped classroom. In the absence of classroom teaching, this system will be a fully virtual course. By using the contrast between the two implementations, a proper assessment and improvement of distance learning will be performed. Finally, the same framework will be implemented in other engineering courses that could cross-disseminate ideas, homework problems and lecture slides.

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