Impact of the Off-Campus Tutoring Industry on Engineering Education

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ABSTRACT

The core objectives of engineering education are to help students establish sufficient fundamental engineering knowledge and develop creative thinking abilities for engineering practices. To achieve this goal, the Accreditation Board for Engineering and Technology (ABET) [1] has designed a list of criteria to measure student outcomes (SO). Based on the criteria, each accredited engineering and engineering technology program develops corresponding indicators to assess the SO areas. With the development of information technology (IT) and artificial intelligence (AI), engineering students are provided with a wide choice of off-campus tutoring and learning services, online help, and problem solution manuals. The services and solution materials definitely help students to understand engineering concepts better and to improve grades and performance in classrooms and labs. However, the services also open the door for plagiarism if they are not used properly. Engineering educators are facing two types of challenges: 1) to adopt innovative information technology in classrooms/labs and 2) to develop appropriate assessment indicators to reflect the SO accurately. This study focuses on the impact of off-campus tutoring and learning services on engineering education. The study is based on the assessment data of the National Assessment of Educational Progress (NAEP) and the survey results of students from the civil, electrical, and mechanical engineering technology programs at Metropolitan State University of Denver (MSU Denver). The discussion presents thoughts on efficient course assessments and improvement.

Keywords: Tutoring, pedagogy, Online-Education, Remote-Learning, Assessment, Chegg.

1. INTRODUCTION

Off-campus tutoring services and homework assistance websites have become increasingly popular among engineering students. Since these services have become a very successful business model, it is necessary for engineering educators to study their impact on engineering education curricula and their assessment. All the off-campus tutoring and learning services promise to help students improve their assignment and exam performances and attain better grades. Most of the services provide students with answers for their assignments while some offer step-by-step solutions of problems that are present in a broad range of engineering textbooks. There are others that even provide instructor’s solution manuals. The survey data at MSU Denver has shown that these services have helped students understand materials presented in classrooms and laboratories better and have improved their grades. However, it has also been observed that the services were used for plagiarism as well.

Traditionally, the engineering education curricula and its assessment system have been developed to help students understand fundamental engineering concepts and develop competencies to design and solve engineering problems in a broad spectrum of engineering disciplines. A good class presentation usually consists of four components. First, instructors introduce students to engineering subjects and the importance of their application. Instructors need to make the subject relevant to real engineering practices. The presentation provides students with a general view of the topic from different perspectives, and how it relates to daily life. A comprehensive introduction to the whole picture of the engineering subject is intended to grasp the attention of students and motivate them to study more with eagerness to find solutions. Second, the instructor shows student technical approaches to engineering problems. In this, mathematical equations and physics concepts are used to establish theory using methodologies and formulas. The objective of this part is to help students develop an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics. Third, the instructor presents examples and procedures to solve problems. This part takes the majority of classroom time, it is intended to help students develop an ability to apply engineering design to produce solutions that meet specific needs with consideration to public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors. Finally, homework, exam, and reports are designed as measurement indicators to assess the students’ learning outcomes (LO).

An increasing number of educators soon began to realize that engineering education must be modified to meet the development of technology and focus on the abilities of creative thinking and problem-solving skills. These are two aspects of the same educational objective. On one hand, scientific and technological innovation have become the driving power of economy and development. New technology and products make life more convenient, healthy, safe, comfortable, while helping to reduce environmental impact. Innovative ideas and their implementation are based on solid mathematical foundations and systematic understanding of physics concepts. Additionally, students need broader knowledge across different engineering and social science disciplines. They need to develop abilities to link the knowledge of such subjects together and solve complex
problems. On the other hand, instead of hiring general engineering graduates, industry and engineering organizations prefer graduates with special skills who can fit in engineering applications in certain professional areas immediately. For example, someone who is skilled in 3D modeling, 3D-printing and design, or robotics may be more desirable professionally than general mechanical engineering graduates. A person with knowledge of renewable energy, compiler coding, or digital sensor programming may feel more welcomed than general electrical engineering graduates. A person with knowledge of waste material recycling; someone who is fluent in computer aided design software, someone who is familiar with Global Information System (GIS) and land survey; or someone who is adept at applying finite element methods to analyze engineering problems may be welcomed more than general civil engineering graduates. Inspired by applied education concepts, some special/vocational educational institutions were established. One such successful institute is 42 Silicon Valley. The institute boosts “Zero Tuition, Zero Teachers, Zero Classes, 100% Coding” [2]. It is a college-level computer programming school with a peer-to-peer learning environment. The school offers an industry-leading educational pedagogy and project-based learning environment and provides computer coding programs that are designed to last three to five years, with students learning at their own pace. The graduates are usually immediately hired by top IT companies.

This type of an engineering education system helps students developing abilities of creative thinking, teamwork, work ethics, communication skills, all of which are lifelong learnings. However, the downside of the system is also obvious. The lack of systematic studies of the theory of mathematics, physics, and other natural science topics may limit the students’ innovative abilities to exploit new areas to solve complex economic, social, and engineering problems. Additionally, 42 Silicon Valley’s style may not be applicable to other engineering disciplines, such as civil engineering, environmental engineering, aerospace engineering, petroleum engineering, etc.

A similar situation occurs in the online and off-campus educational sector.

2. OFF-CAMPUS TUTORING SYSTEMS

The off-campus and online tutoring system is a fast-growing industry in this sector. Information technology (IT) has developed to such a stage that people can find almost any information online. IT has significantly improved the quality of daily lives and has helped people live more convenient, healthier, safer, and knowledgeable lives. For instance, people can effectively choose products, services, or medical providers that can lead to their welfare. In the education sector, the size of the private off-campus tutoring market reached $347.31 billion in 2020, with an incremental growth in 2021 of $8.37 billion at a rate of 6.90%. The demand is increasing with the impact of the coronavirus pandemic and the rising popularity of personalized learning. It is estimated that during 2021-2025 “the market’s growth momentum will accelerate at a compound annual growth rate (CAGR) of 7.61%” [3]. Off-campus tutoring systems provide a variety of services to students, faculty, parents, and adult continuing education from preschool to college education levels. The system strengthens and influences traditional education in many ways. This paper will focus on the impact of the off-campus tutoring system on STEM education only.

Among many off-campus tutoring services, Chegg is one of the most popular and successful ones. The $12 billion company, located in Santa Clara, California, has its heart of operations in India and has hired more than 7000 employees worldwide with advanced math, science, technology, and engineering degrees. The off-campus tutoring giant provides 24/7 online step-by-step solutions and expert answers to the questions posted by subscribers. Chegg has gathered solutions from more than 34,000 ISBN textbooks, covering topics in biology, business, engineering, mathematics, and science [4]. The database is still increasing as Chegg pays for educators to upload approved exam practices, study guides, lecture notes, practice quizzes, case studies, and lab assignments that these educators have created. According to Chegg’s own reports, there were 6.6 million subscribers in 2020 [5], costing $14.95/month for each subscription for homework assistance only. The subscribers can get additional help in quizzes, exams, mathematics, and writing if students pay $19.95/month. There is an estimation that the number of students actually using Chegg are more than the subscribers since it is common for some students to share the cost by using one subscription across multiple users.

In order to understand the service provided by Chegg, authors subscribed to the Chegg Study Pack to try to get help on different topics in civil engineering and mechanical engineering. Chegg allows each subscriber to access to up five (5) textbook solution titles per month and to post up to twenty (20) questions per month. Chegg writing allows up to 30 Expert Checks per month. Test results show that Chegg has step-by-step answers for all problems in most current edition engineering textbooks adopted at the Department of Engineering and Engineering Technology at MSU Denver. However, Chegg does not provide the solutions related to previous edition of textbooks since Chegg also provides textbook buy/rental services to students. Authors also posted problems written by themselves that were not present in any textbook. The problems were previously assigned to the students as homework and exam questions in the undergraduate classes of Mechanics of Materials and Thermodynamics. Surprisingly, the problems had been posted by students before and Chegg had provided step-by-step solutions too. In general, Chegg provides relatively good answers for K-12 and undergraduate STEM problems.

Chegg is not the only online tutoring service company in the world. Several popular similar tutoring services are available to students and their parents, such as Learn To Be, Tutor.com, Preply, Skooli, Pearson’s Smarthinking, TutaPoint, and Mathnasium. Youtube and Amazon also provide solutions to problems in different science and technical subjects. Students and their parents from grades K-12 to college may choose different types of online tutoring and learning services based on their needs. Online tutoring services integrate educational resources nationwide and globally, and allow students/parents to access the best educators and online classes. Students don’t have to stick to “bad instructors” or have to learn from a single teaching style. This eliminates regional educational differences and makes education cost effective. People in remote areas have the same opportunities to access top quality education resources as people living in more affluent and urban areas do, and that too at reasonable cost. Online tutoring and learning services have also significantly improved pedagogy in many aspects, having opened various types of education resources to instructors as well. Instructors can now adopt the most recent pedagogical research achievements to their classes. Most textbook publishers provide teaching support through instructor resources, which include...
instructor solution manuals, comprehensive lecture PowerPoint presentations, example problems, image banks, charts, and tables. Some publishers also provide instructors with video clips, software and problem-solving tools to support lectures, and laboratory experiment-based education. Instructors don’t need to spend too much time on technical details, and they have more time to focus on pedagogical improvements and helping students understand principles better. The objective is to provide students with a diversified learning environment, help them understand fundamental scientific concepts, and use methods of systematic approaches to engineering problems.

The development of online tutoring and learning services also presents a challenge for students and educators. For students, it requires an active learning attitude and self-discipline. Online tutoring and learning services usually do not provide program curricula, so it works better for certain subjects than others. For instance, student learning outcomes for social science, foreign languages, and computer programming subjects are better than that of civil engineering, electrical engineering, and mechanical engineering since the latter need systematic understanding of math, physics, and engineering principles. For STEM educators, students can get answers online with relative ease so assessments based on correct answers may mislead and the results may not truly reflect the real learning outcomes of students. In fact, the assessment data from National Assessment of Educational Progress (NAEP) and the Department of Engineering and Engineering Technology at MSU Denver showed concerns for science and engineering educators.

3. ASSESSMENT RESULTS IN SCIENCE FROM NATIONAL ASSESSMENT OF EDUCATIONAL PROGRESS (NAEP)

Chegg claims that 94% of their customers get better grades when they use Chegg to understand their coursework. Students gave their testimonials online to support Chegg’s statement. However, the assessment data from NAEP and the department of Engineering and Engineering Technology at MSU Denver showed mixed results.

![Figure 1. Summary of 2019 Student Performance in Science (NAEP, 2019)](image)

Figure 1 shows the NAEP summary of student performance at grades 4, 8, and 12 in Science from 2009 to 2019. The assessment data covered three content areas: Physical Sciences, Life Sciences, and Earth and Space Sciences. The data clearly shows that the average scores for high performance students improved in the past ten years while the scores for lower performance students continue declining. “NAEP Mathematics and Reading results show a troubling pattern from 2009 to 2019: scores for higher performers improved while scores for lower performers declined” [6]. The assessment results have been studied by educators and administrations, and people are trying to explain the phenomenon from different perspectives. The authors believe that online tutoring and learning services is one of major factors contributing to these results. Higher performance students tend to actively use open educational resources and environments to improve understanding of scientific subjects and get additional help from online tutoring services. In contrast, some of the lower performance students may simply copy and paste the answers from the online tutoring service when they are stuck on comprehensive homework problems. Their performance seems to have declined whenever online resources have not been available. Similar assessment data reflects the same issues for students in the department of Engineering and Engineering Technology (EAET) at MSU Denver.

4. ASSESSMENT RESULTS IN ENGINEERING AND ENGINEERING TECHNOLOGY AT MSU DENVER

Faculty members at the Department of Engineering and Engineering Technology at MSU Denver have noticed that in most courses, there is a substantial difference in scores between take-home assignments and in-class examinations. In some courses offered at the department, the differences recorded are as large as almost thirty percent. For example, in one of the thermodynamics courses in Fall 2016, the homework assignments averaged at 95% or higher while the in-class exam results show a class average of about 75%. Communication with students indicates that an increasing number are taking advantage of off-campus tutoring and learning services.

The authors decided to learn facts about off-campus tutoring and learning services using a simple survey with six questions. The surveys were conducted during the Fall 2016 and Spring 2017 semesters in several different junior level classes where students are considered to be serious in pursuing their degrees (the retention rate from junior to senior has been 80% or better at EAET, MSU Denver, which indicates that students at junior level have a very good chance of finishing their degree in the engineering and engineering technology area). Participating students majored in civil, electrical, and mechanical engineering technology. The main objectives of the survey were to check 1) if outside-of-the-classroom aids are needed, 2) what kind of assistance the students usually utilize, and 3) how effective or useful they are. The percentages reported are rounded up to closest integers.

1. Students do need outside-of-the-classroom help
The first survey question is whether a student needs help outside of the classroom or not and, if so, then how often. About 29% of the students answered that they needed help with almost every assignment; 63% indicated using help as needed, and the rest reported that they never needed any help outside of the classroom. This concludes that about 92% of the students in their junior level classes do need help and use sources outside of the classroom, referring to Figure 2 (Percentage of Students Who Need Outside-of-the-Classroom Help). Since the survey was anonymous, it was difficult to track the difference in grades between students who used outside-of-the-classroom help and those who did not.
The next question aimed to check the percentage of students who used in-person help, including consulting with the instructor or their classmates. As shown in Figure 3 (Percentage of Students Using Online Services vs. In-Person Help), 67% of students checked “Yes” to confirm their usage of in-person help. This number should be considered in conjunction with previous figures, i.e., it is 67% out of the 92% students who used in-person help outside of the classroom. This concludes that about 62% of total students used in-person help of some kind. When answering if they used online help, 93% students said “Yes”. Using reasoning similar to previous, this number is within the 92% of students who use outside-of-the-classroom assistance, which means that about 86% of the students in junior level classes were using online services for their homework assignments.

The figures tell us that the majority of junior level students need outside-of-the-classroom help and gives us a clear picture of the utilization of outside-of-the-classroom help and taking advantage of online or in-person help.

The survey shows that 77% of students consider off-campus tutoring and learning has helped improve their grades and 80% of students believe that the services helped them understand the subject better. These numbers are close to the claims made by Chegg.com.

3. Online Services vs. In-Person help

The technology vs. teacher debate occurs each time that a new form of technology comes along: handwriting, paper books, radio, TV, cassettes, video cassettes, and computers. The conclusion in such debates is usually that technology, while it offers varying level of help in education, is merely an aid to teachers but not a replacement of them. When we asked students how the online services compare to in-person help, results showed that about 37% of the students considered that in-person help is better, about 13% said that online was better, about 20% said that they were both equal, and the rest were not sure about their answers. This is shown in Figure 5 (Online Services vs. In-Person Help Comparison – Overall results).

The results show a slight change in a few areas: 1) 82% of students claim that the online resources helped them improve their grades and 2) 85% believe that online resources helped them in understanding the materials better. When comparing effectiveness, more students believe that in-person help is better than online resources, as shown in Figure 6 (Online Services vs. In-Person Help – Comments from Students Who Have Used Both In-Person and Online Services).

The survey results confirm the assertion that technology is an aid to teachers but not their complete replacement.
The survey data and assessment results of NAEP show that the majority of students are using online tutoring and off-campus services. The services have helped them understand the materials better and even achieve better grades in school. Engineering educators should pay more attention to online tutoring services and continue improving engineering pedagogy. There are many other details that are yet to be uncovered, however, such as the kind of data that is needed for strategies to guide students in using those services properly, the kind of impact that the online tutoring services may have on class assessment or student outcomes, and the type of future studies that are needed in order to help students achieve program educational objectives (PEO) and their goals in education.

ABET has developed a series of criteria and guidelines to measure student outcomes in engineering based educational institutes. The criteria (a) to (k) have been adopted nationwide to ensure an accredited engineering institute provides students with sufficient fundamental engineering knowledge to practice in relevant fields. The measurements of the SO were based on indicators developed by instructors, which may be homework problems, exams questions, in-class or out-of-class projects, laboratory performances and reports, senior projects and presentations, undergraduate research papers or theses, and student peer evaluations. The development of off-campus tutoring and learning services should help improve the quality of STEM education. The assessment data of NAEP and the data at MSU Denver have brought up questions to engineering educators and current assessment systems. There are still many questions that need to be answered: “What should be the focus of current engineering and engineering technology education? Is the current SO assessment system or better ‘grades’ effectively and truly reflecting the qualities of engineering education? Does the engineering education system meet the needs of technology development and challenges of current engineering practices in industry?” The design of the assessment indicators may prove to be a challenge in the age of Artificial Intelligence. Innovative and comprehensive indicators should be developed to measure SO thoroughly and appropriately.

5. SOME SUGGESTIONS TO IMPROVE STEM EDUCATION AND STUDENT LEARNING OUTCOMES (LO)

Students often are in need of after-class assistance. If they cannot get it on campus, they pay for off-campus or online resources. As was shown in the NAEP assessment data and MSU Denver survey, higher performance students tend to have a better understanding of engineering principles and lower performance students tend to get the correct answers for their homework and plagiarize work by using online tutoring and learning services. In such situations, what can educators do? Critics point fingers to Chegg and other online tutoring services for unethical business operations and for encouraging systemic cheating. Chegg CEO Dan Rosensweig has fought back and mentioned that Chegg’s model was “not built” for cheating but “always put students first”. With the rapid development of artificial intelligence, online tutoring and learning services will become increasingly popular and convenient. It is time for educators to face the challenge and create innovative pedagogical methods to improve traditional education systems.

First, educators have to accept and adopt AI technology in their classroom. As engineering practice has changed significantly in the past decades, engineering education also needs to be reformed accordingly. With the development of computational technology, the solutions to mathematical equations are no longer a major obstacle in engineering practice. Advanced manufacturing tools and powerful construction equipment are now eliminating human errors and can extend the abilities of engineers to levels far beyond what human beings could reach before. As engineers are getting more help through computers and other technical ways, the development of creative thinking and innovative solutions to engineering problems has become crucially important for engineering students. The development in industry and technology require engineering students to have a solid understanding of fundamental engineering concepts and principles. Rather than to “go deeper,” the curricula should encourage students to “go broader” to explore the application of scientific principles in practice. AI should be included in engineering curriculum and should encourage students to become familiar with current progress in industry practices. Educators should be encouraged to adopt project-based learning for junior and senior students if the topics are applicable. In addition, instructors may also want to consider eliminating traditional homework methods and provide students with review problems. Student learning outcomes may be more accurate if the assessments are based on in-class quizzes and exams, which focus on fundamental principles and concepts.

Second, schools and universities should provide more accessible and freer on-campus or online tutoring help for students. Currently, most universities in the U.S. have academic advisory, teaching assistant (TA), and tutoring service programs. However, these programs are not sufficient to meet the needs of students. One suggestion could be for the universities to partner up with off-campus and online tutoring services to provide students with 24/7 access to assistance. The services should not be simply be providing answers, rather they should require the engagement of faculty members in the services. MSU Denver and other education-oriented universities require a 24-credit hour teaching load per academic year for each faculty. The policies have to change to avoid overwhelming instructors by engaging in after-class tutoring services. In the U.S., almost all universities have adopted certain learning management systems (LMS) in their systems, such as Blackboard and Canvas. Similar approaches may be applied to online tutoring and learning services.

Third, federal and state governments can help establish policies, guidelines, and rules for accreditation for practicing off-campus tutoring and learning services. Education is fundamental to the national security and national economic development and growth [7]. It helps in improving the lives of people and it is important.
for people to keep their social value and maintain social justice. Off-campus tutoring and learning services should be integrated in national education regulation systems. The government plays an important role in education. In July 2021, the Ministry of Education of China released the “Guidelines for Further Easing the Burden of Excessive Homework and Off-campus Tutoring for Students at the Stage of Compulsory Education”. The policy strictly limits the activities of off-campus tutoring and learning services. This caused panic and the $120 billion sector in China crashed overnight [8]. The authors do not recommend this policy at all. Instead, government education agents and regional districts should establish policies to encourage off-campus tutoring and learning services engaging in traditional education systems. Special tax brackets should be implemented for organization that provides affordable AI products licenses for educators. In general, regulated and assessable off-campus tutoring and learning services will help build a more healthy and user-friendly learning environment for students and educators.

6. CONCLUSIONS

The development of information technology and online tutoring technology has provided engineering students and educators with a broad choice of tools, methods, and opportunities for fundamental engineering education. When educators encourage students to get help from online and other tutoring services for their homework and projects, they are also facing new challenges of possible systemic cheating. A study at the Department of Engineering and Engineering Technology at MSU Denver shows that off-campus tutoring and learning have been widely used by most engineering students. The services helped students improve their grade and performance in classrooms and labs. On the other hand, the assessment study also showed inconsistent results between individual engineering assignments and comprehensive engineering assignments for certain groups of students. One reason is that most off-campus tutoring services only provide students with solutions and simplified procedures for individual homework problems, creating a possibility of plagiarism and discouraging creative thinking attitude if the services are not used properly. This study has explored a new pedagogical area in engineering education. The improvement of homework grades does not necessarily reflect better understanding of engineering concepts. It is crucial for educators to understand the impact of AI technology on the traditional engineering education system and its assessments. Adjustments have to be made accordingly for the traditional curriculum, class presentations, and assessments of engineering education. Further study is needed to bring educators, off-campus tutoring, learning providers, and the industry together to integrate the educational resources and create an innovative engineering pedagogical system.

7. REFERENCES

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