

Work-Integrated and Cooperative Learning Effects on Micro-Electronics Design Classes

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Cooperative learning and work-integrated learning are the latest trends in information delivery at high schools and universities. In cooperative learning, teachers organize students' interactions and educate them to work in small groups to enhance each other's learning. Whereas, work-integrated learning, is a type of experiential learning that allows students to participate in real-world work during their studies. Both approaches help bridge the gap between theoretical knowledge gained from classrooms and professional market needs. Electrical engineering is a field that could highly benefit from such a scheme. Having to be continuously up-to-date with the latest advances in the field of micro-electronics is difficult. Consequently, Several challenges are imposed on faculty members and academics who teach micro-electronics circuit design courses in electrical engineering for senior undergraduate or graduate students. This paper presents a case study of the apparent benefits and effectiveness of cooperative learning and work-integrated learning in the Electronics II and VLSI classes offered at a university. Furthermore, it aids programs in electrical engineering to meet ABET students' outcome (4).

Keywords: ABET, cooperative learning, work-integrated learning, critical thinking and problem solving, micro-electronics teaching

INTRODUCTION

Cooperative learning is an educational technique that has been thoroughly investigated and proven to be an effective method of information delivery [Abramczyk and Susanne, 2020; Loh, Chee-Yen, and Chin-Siang, 2020; Jacobs, 2002]. The technique aims to organize classroom interactions into academic and social learning experiences by dividing a classroom of students into small groups so that they capitalize on one another's knowledge and skills. On the other hand, cooperative education also known as work-integrated learning (WIL) [McNeil et. al, 2017; Jackson, 2015; Orrel, 2004] is a partnership formed to connect universities and industries which allows students to achieve and improve practical experience in their field of specialty. Students, faculty, and industries have greatly benefited from such partnerships. Students can

be exposed to professional working experience in their respective fields prior to graduation. Faculty members may help students prepare for professional employment by guiding their research skills to uncover recent concerns and needs in society and industry, and then cooperatively identifying solutions to those problems [Du Pre, 2010; Trede, 2012; Miron, 2022]. This can improve the quality of university courses and aids in incorporating up-to-date content. Students face several challenges in shifting from higher-education environment to full-time employment [Authur and Flynn, 2012]. This is due to fresh graduates' lack of professional skills [Mourshed et. al , 2013]. This problem intensifies along with the reduced spending on employee training by employers [Lynch, 2007; Bores-Garcia et. al, 2021; Hamadi et. al, 2021] creating a deadlock problem. Society and stakeholders expect Higher education institutions (HEI) to prove their concrete efficiency and effectiveness. Fierce competition in the current digital era and pay disparities between talented and unskilled employees [Khampirat, 2021] raise the pressure on HEIs. This problem might have a significant impact on the major of Electrical Engineering. This is due to fact that it is tough to keep up with the current breakthroughs in the field of microelectronics on a constant basis. New engineering graduate employment is linked to an increase in the need for highly skilled engineers in order to promote economic effectiveness and long-term social progress [Stehens and Rosch, 2015]. However, in some countries, obtaining competent graduates to enter the sector is problematic [Kim, Chang, and Castro, 2020; Khampirat and Pop, 2017]. Learning outcomes (LOs) are statements describing the knowledge, competencies, and attitudes [Spady, 1994] that students are expected to achieve after completing a higher education degree [Gonzalez and Wagenaar, 2008]. They are used to assess graduate quality. LOs are also recognized as a vital basis for assessing the success of HEI professional advancement through learning experiences [Suskie 2009], and they are commonly utilized as crucial criterion for engineering program accreditation [ABET, 2017]. According to studies, existing students frequently lack a comprehensive knowledge of their LOs [Brooks et. al, 2014; Jorre and Oliver, 2018; Bralic and Divjak, 2018]. Work-integrated learning (WIL) experience has been shown to be an effective approach for enhancing LOs in previous research [Brahimi et. al, 2013]. WIL is a kind of experimental learning that allows students to actively participate in practical professional work whilst contributing to student progress and the construction of a sustainable society through career development [Nguanmanasak and Khampirat, 2019]. Despite the fact that much attention has been paid to how university support services strengthen students' self-efficacy and LOs as they transition into employment [Wernersbach, 2014; Wibrowski, Matthews, and Kitsantas, 2017], little previous research has been conducted on how LOs formed through WIL are mediated by life-long learning skills, career performance expectancy, and self-efficacy, given that WIL program participation has an indirect rather than direct effect on LOs. Cooperative education students are exposed to both academic and work environments that help them develop crucial work related skills [Dressler and Keeling, 2011; Rowe and Karsten, 2017]. Graduate employability is a major objective of international education policies [Helmrich et. al, 2012] and is a vital indicator for measuring the value of universities education [Burke et.al, 2017]. With the rapid development of the electronics industry, the professional occupational program of electrical engineering expertise has passed the current learning media that is being used to support the learning process [Hamid et.al, 2020]. Hence, huge challenges face advanced and graduate-level courses. This paper introduces a test case for Electronics II course and a senior-level VLSI design class offered at a university. It is evident that students who were acquainted with professional industrial experience scored best among their colleagues. The paper is organized as follows, section 2 introduces the cooperative education concept and its methodology, section 3 presents the results obtained from a Electronics II and senior-level VLSI classes. Section 4 discusses the effects of WIL on entrepreneurship. The impact of COVID-19 on the educational process is presented in section 5. Section 6 concludes the paper and elaborates on the findings.

COOPERATIVE EDUCATION

Since its introduction in 1906 as an experimental education program for engineering students at the University of Cincinnati, cooperative education has become an essential component in the framework of many engineering schools across the world [Barber and Fortnberry, 2088; Blair, Millea, and Hammer,

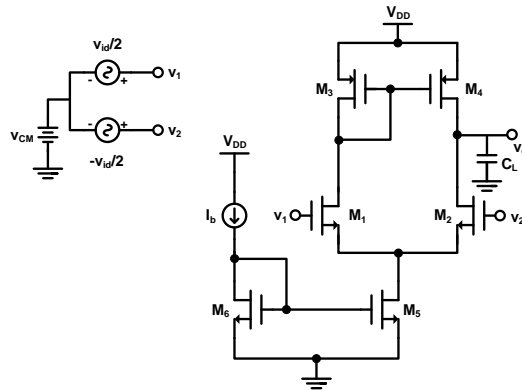
2004]. It allows students to engage in practical education by combining academic course work with practical job experience. There is relatively little evidence available on how engineering instructors support and implement cooperative education-based learning into their teaching techniques [Barber and Fortnberry, 2088]. This is attributed to the confined nature of higher education engineering programs as they do not relate to up-to-date real-world problems. This is due to the fact that publishing latest trends and advances in electrical engineering in textbooks consumes heavy time. Furthermore, faculty members may not have the capacity and background to fully educate students about these advances. Moreover, technology is a critical enabling factor that is being adopted by students to support their learning process [Liyanage et. al, 2013]. Hence, the learning content should be continuously up-to-date with technological progress and trends [Zhang et. al, 2018]. Under the new economic system, the education process should be guided by social demands, which incorporates a combination of multiple education links of self-learning, lifelong learning and individualized learning. Students can obtain differentiated individualized knowledge content throughout the cooperative education system. Whereas, the traditional education model of engineering is characterized by a non-adaptive, non-flexible, single way old content. Thus, cooperative education is a powerful way to infuse the educational program into a real world application. Learning outcomes (LOs) serve as a critical basis for assessing higher education institutions' performance. LOs have been recognized as a criterion for academic program accreditation. Nevertheless, little is documented about the reason students' intended outcomes differ and how working experiences and learning practices affect LOs differently.

ABET reinforced a set of professional competencies while formulating its new engineering accreditation requirements that includes understanding ethical and professional responsibilities while being aware of contemporary issues and recent advances in the respective field of engineering [ABET, 2019]. This requires that ABET-accredited institutes should alter their education environment from a classroom-oriented environment that pursues solely academic performance into an educational environment of the unity of knowledge and actions. Hence, forming a training environment that can respond to, participate in, and solve emerging social engineering problems [Usman and Jospeh, 2019]. VLSI is an advanced field that can immensely benefit from cooperative education. This is attributed to significant developments in the concepts of data storage, networking, energy harvesting, and Internet of Things applications [Ishibashi, Koichiro, and Nobuyuki, 2017]. As a result, the need for dependable high-performance integrated circuits that support such applications is growing [Prasad, 2018]. VLSI enables developing complex semiconductor and telecommunication blocks, relying on analog/digital design techniques introduced in Electronics II. Therefore, design engineers should be acquainted with ingenious research skills and contemporary knowledge to identify prevailing problems and create inventive solutions.

COOPERATIVE EDUCATION EFFECT ON ELECTRONICS II AND VLSI STUDENTS

In Electronics II class, students were assigned a project to design and simulate an active-loaded MOS differential pair which is essential in the design of high-performance amplifiers. Figure 1 shows the active-loaded MOS differential pair.

FIGURE 1
ACTIVE-LOADED MOS DIFFERENTIAL PAIR



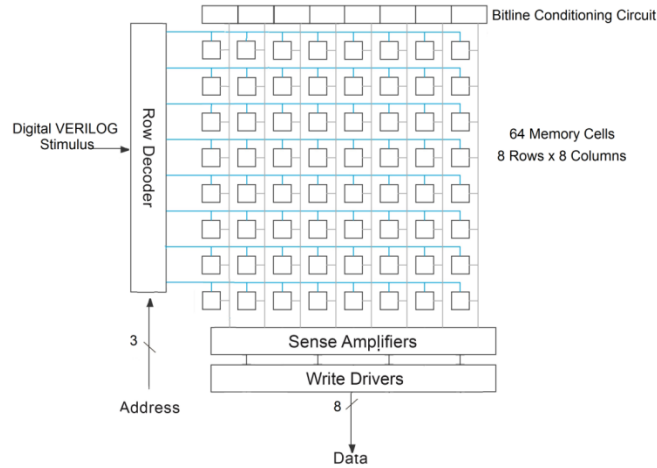
Using proper design tools, students were asked to implement the design while satisfying a set of design constraints including speed, power, and area. To meet such requirements, students must appropriately modify a number of transistor-level features. Table 1 lists the specifications and constraints for the differential amplifier.

TABLE 1
ACTIVE-LOADED MOS DIFFERENTIAL PAIR DESIGN CONSTRAINTS

Technology	180nm CMOS
Minimum input common-mode voltage (V)	0.8
Maximum input common-mode voltage (V)	1.6
Unity-gain frequency (MHz)	5
Slew Rate (V/ μ s)	6
Supply voltage (V)	1.8
Load capacitance (pF)	15

Accordingly, in a senior undergraduate-level VLSI design class, students were assigned a midterm project to design, test, conduct the layout and validate the operation of a 64-bit memory system. Due to having several design elements and blocks, such project will enhance the design thinking and problem-solving capabilities of students. Figure 2 illustrates a simplified top level schematic of the memory system.

FIGURE 2
64-BIT MEMORY ARRAY



Using multiple advanced design tools, students were asked to comply to a set of challenging design requirements including speed, power, and area, among others. For the design to achieve and comply to such specifications, students should properly fine-tune numerous transistor-level parameters in their designs such as transistor sizes (width and length) and operating conditions. Table 2 lists the specifications and requirements for the memory system.

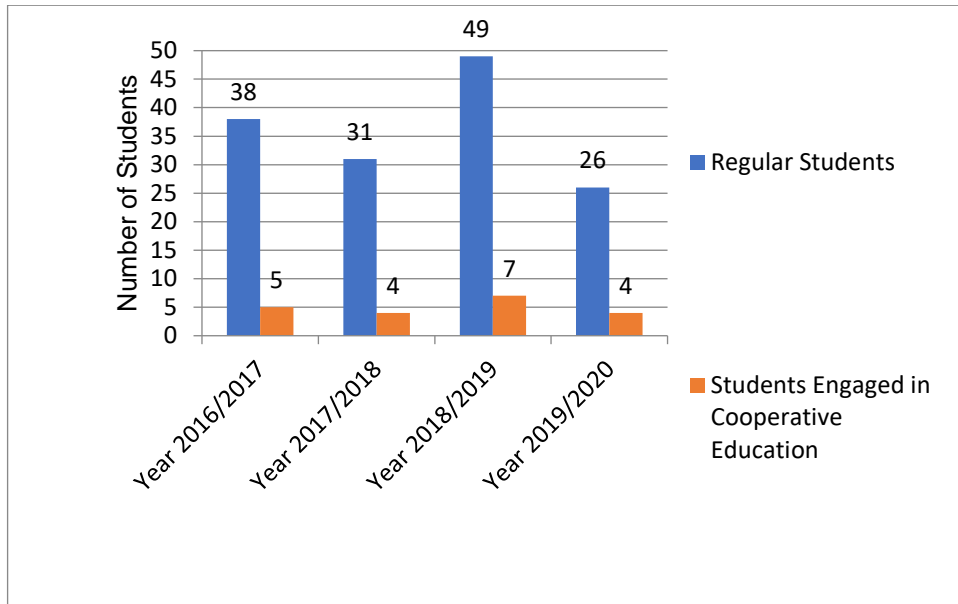
TABLE 2
MEMORY DESIGN SPECIFICATIONS

Technology	28nm CMOS
Memory Array Size	8×8
Supply Voltage (V)	1±10%
At Speed Power Consumption (mW)	0.6
Maximum Read Access Time (nS)	50
Maximum Write Time (nS)	50
Maximum Layout Area (µm ²)	2200

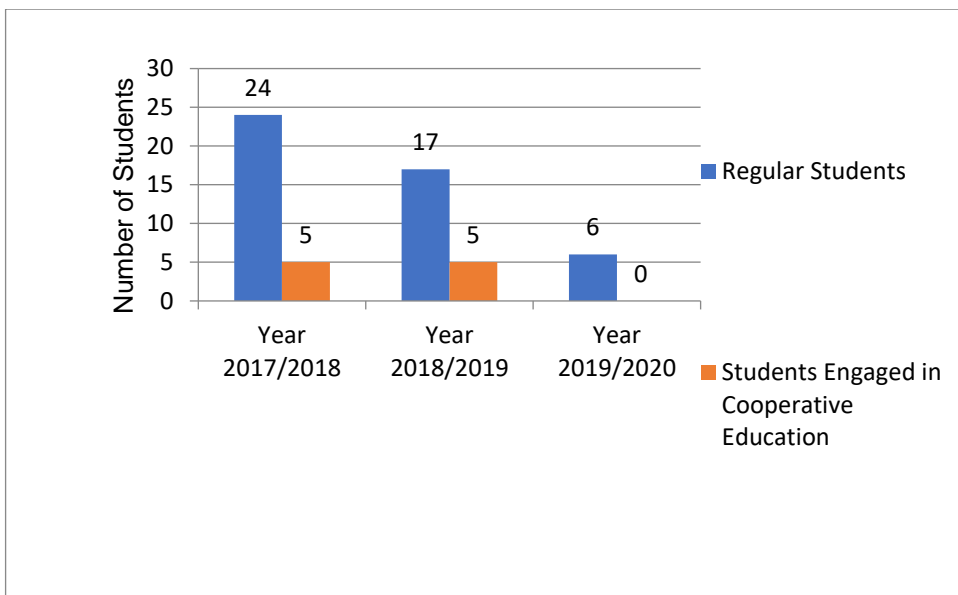
To abide to the requirements in Table 2, students should have a deep understanding and an in-depth theoretical knowledge about circuit behaviour and operation and MOSFET devices' properties and characteristics. Such theoretical knowledge can be highly improved by applying critical thinking, problem-solving, and design thinking concepts [Abugharbieh and Marar, 2019; Ghanizadeh, 2017; Carvalho et. al, 2017]. Furthermore, being equipped with the latest advances in the micro-electronics field is immensely beneficial [Bozanic and Saurabh, 2017]. Being a senior-year level course, students are acquainted with various differentiating design thinking qualities and techniques. This is due to the fact that problem-solving and design thinking are an accumulative process that progresses throughout the students' educational period and is affected by various external factors [Nair et. al, 2017]. On the other hand, knowledge regarding latest trends in micro-electronics can best be gained from interaction with leading industries in this field.

Statistical information have been collected through the past four years during which 164 students enrolled in Electronics II class and 57 students enrolled in the VLSI class. Prior to registering in the course, several students engaged in cooperative education programs around the world. Figure 3 represents the statistical data of Electronics II students whereas the statistical data of VLSI students is illustrated in figure 4.

**FIGURE 3
ELECTRONICS II COURSE STATISTICS**



**FIGURE 4
VLSI COURSE STATISTICS**



Since cooperative education work experience contributes significantly to a student's overall academic achievement, the classroom learning ambiance and the information provided in class were definitely influenced. The attendance of students with cooperative education experience significantly improves the learning environment in the classroom. This is due to students contributing professional opinions and judgements to classroom debates based on their work-integrated learning experiences. As a consequence of their WIL experience, cooperative students are more fitted and prepared to absorb the course material offered in class. Furthermore, the overall level of information presented throughout the class was elevated

since cooperative education students tend to ask more relevant and advanced questions during the class compared to regular students. Hence, incorporating work experience within the course curriculum is an effective teaching strategy that encourages students to act as autonomous learners. This, in turn, supports the development of critical thinking, problem-solving, leadership, teamwork and many vital practical skills [Kong et. al , 2014]. ABET defined students' outcome (4) to be the ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts. Such vital meta competencies can be easily acquired by cooperative education learners. WIL students' performance was measured against other students. Results are presented in figures 5 and 6.

FIGURE 5
AVERAGE STUDENTS' SCORE STATISTICS IN ELECTRONICS II COURSE

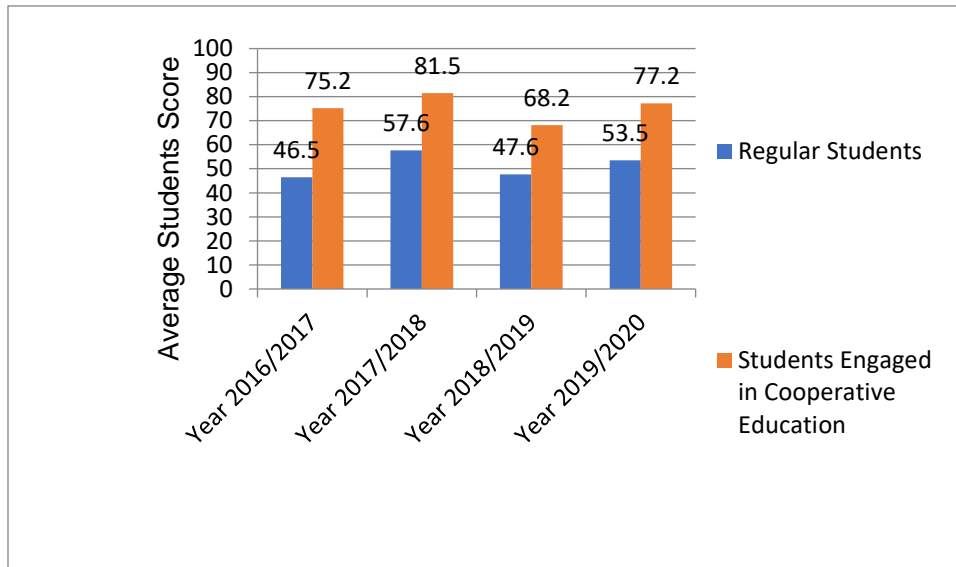
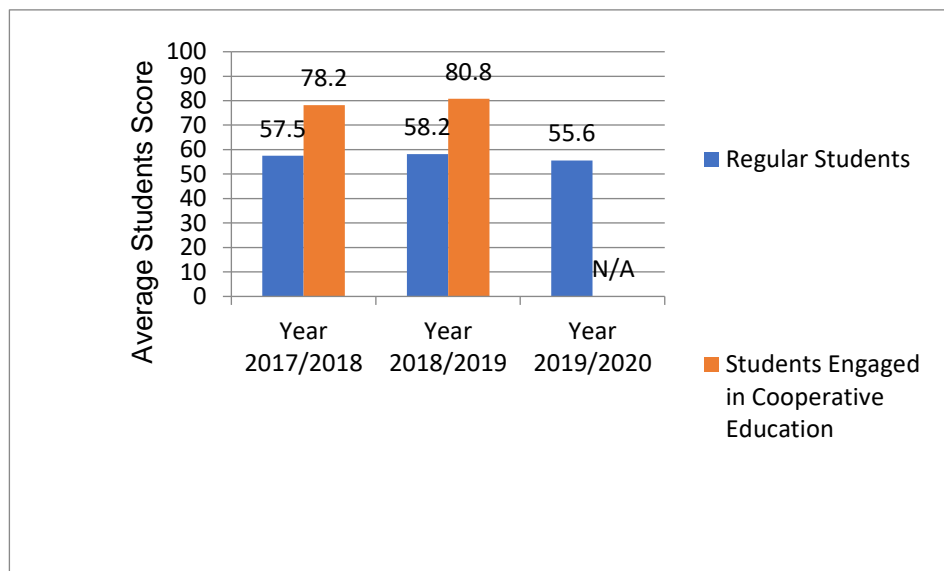


FIGURE 6
AVERAGE STUDENTS' SCORE STATISTICS IN VLSI COURSE



As seen in figures 5 and 6, due to their work-integrated learning experience, cooperative education students are more induced and qualified to excel in classrooms than non-cooperative students. Based on the presented results, faculty members should encourage and endorse students to enroll in professional training especially in senior years.

WORK-INTEGRATED LEARNING IMPACT ON THE DEVELOPMENT OF ENTREPRENEURS

Entrepreneurship surpasses the creation of new businesses into innovativeness, risk assessment, proactiveness, and having the potential to resolve challenges in a creative manner contributing to the development of an organization. Therefore, during times of uncertain job market, entrepreneurial WIL programs may prove to be a viable option for professional skills development. Golden Electronics is Jordan's leading provider of integrated circuit design services. It offers cutting-edge digital and analog circuit design services. The firm was founded as a start-up by a couple of the university's Electrical Engineering graduates who took the Electronics and VLSI courses and engaged with WIL during their studies. The firm now employs more than 50 skilled engineers and designers and provide its services worldwide. Another firm developed by the university's Engineering graduates is Mind Rockets. By converting text into sign language, the business creates assistive technology solutions for the Deaf. The firm provides services to major websites and has won several entrepreneurial awards throughout the world. Both companies, among many others, continue to actively engage the university students through visits and seminars incentivizing them to participate in field training and WIL opportunities. The university graduates are regularly approached by businesses and start-ups seeking employment. As a result, WIL has been recommended by successful entrepreneurs as a way to ignite entrepreneurial passion in students and to provide a better learning environment for entrepreneurial-minded students than traditional classroom learning. WIL environment expects students to be innovative, resourceful, and resilient, all of which are qualities of a successful entrepreneur.

COVID-19 EFFECTS ON THE TEACHING PROCESS

The outbreak of Corona Virus, which shook the planet, swiftly became a worldwide upheaval. 2020 became the year that completely transformed human interactions in the world. The Covid-19 epidemic has created tremendous health, political, economic, social, and educational issues, and had a major impact on life to this day. With the presence of social distancing and its necessity to slow the spread of the virus, the structure of human interactions is altered. Education, like many other disciplines, has been heavily impacted. Universities and institutes had no choice but to adjust to the pandemic through online teaching. As a result of this instant transformation, a significant stain was placed on instructors, students and parents [Johnson et. al, 2021; Bellini et. al, 2021]. Without the synergy of suitable learning methodologies and in-class discussions leading to significant contributions to the learning process, certain courses, particularly Electrical Engineering core courses, will be less meaningful. Students may have found it challenging to sustain their academic motivation as a result of the quick change in teaching methods. As of April 2020, 85 percent of students globally were absent from schools, colleges, and universities owing to curfews [; Schleicher, 2020; Marinoni, 2020]. Italy has been one of the most afflicted countries in the world by the Covid-19 outbreak. Italy's schools and colleges halted academic operations on February 24, and the country was declared closed on March 9. As the new Corona Virus spread throughout Europe, other national governments took similar precautions [Zaccoletti et. al, 2020].

Distance education may be stated to have a good impact on the continuation of education in the event of an outbreak and can be utilized as an alternate learning choice for lecturers and students. Good preparation, on the other hand, is essential for the proper execution of distant education activities [Ana et. al, 2020; Gaur et. al, 2020; Usak et. al, 2020]. A variety of challenges occurred during online learning and affected the teaching quality. The availability of the internet at all times and the fact that instructors and students are not yet habituated to utilizing online learning platforms are major obstacles that hindered the

learning process. Moreover, as a result to the pandemic, all enterprises were compelled to close. Hence, students were unable to engage in field training and were instead obliged to attend video classes. This meant that work-integrated learning competencies were missing from the learning process. In an attempt to maintain the quality of information delivery, tutors capitalized cooperative learning during their online lectures. Being active, doing tasks in groups, presenting an explanation to a group of friends, encouraging their group members to participate actively, and debating about certain problems are all actions that students were encouraged to engage in during online teaching. Despite such efforts, it was difficult to maintain the same level of teaching. In return, design projects were simplified, and class topics were not as complex as before. This resulted in improper student evaluations. Noticeable difference in students performance can be seen during this semester, during which, in class teaching was resumed for the first time since 2020. Therefore, although distance education process has many advantages, there are many obstacles to the successful implementation of distance education in higher education institutions, such as internet network infrastructure, students' and teachers' lack of computer competence, and students' and teachers' effectiveness in using technology. Hence, It may be stated that the remote education system, which was adopted as a result of the Covid-19 outbreak, did not please students nor lecturers in higher education institutes in general.

CONCLUSION

Educational institutions need to prepare and incorporate modern teaching tools within the curriculum. There is a huge demand to equip students with meta competences going beyond traditional knowledge. Hence, education, needs a transition from simply transferring knowledge to developing individual potentials with the help of cooperative education. Cooperative education can serve as the missing link between theoretical knowledge in pedagogy sciences and the modern practical implementation in businesses. Work-Integrated Learning (WIL) programs, according to graduates, offered mentoring, an optimistic attitude on the future, and strengthened their confidence and entrepreneurial spirit. Therefore, it meets the vital criteria for effective 21st century learning by facilitating and inducing critical thinking and problem solving concepts. It thereby leads to a conversion from the transfer of knowledge to the development and deployment of individual potentials. Advantages of cooperative education proved to be beneficial to students, faculty members, and businesses. This work has resulted in a positive experience for the participants and improved the quality of knowledge.

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