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Non-traditional Delivery of Hands-on Manufacturing Courses

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Non-traditional Delivery of Hands-on Manufacturing Courses

Abstract

Due to recent COVID-19 social distancing policies and procedures, there was no way to offer hands-on courses in an on-site format for many education institutions. The solution employed by many educators was to find new ways to implement web-based delivery tools and technologies in order to maintain course learning outcomes and help students successfully grasp course content. In this review paper, a number of innovative practices is highlighted used to deliver course content in several ways. Overall, the paper reports a number of available delivery mechanisms that could be implemented for several manufacturing courses and programs.

Introduction

Offering the engineering and technology courses in regular on-site delivery mode was not a possibility for many technical educators during the COVID-19 Pandemic [1]. The goal for these educators was to maintain the academic success of their students and continue to meet course learning objectives and the student outcomes of their programs.

Although local hands-on and/or laboratory-based components of any technical course were not an option for educators, including any type of senior design and/or capstone projects, all teaching activities including the term and innovation projects were instructed and practiced virtually to help students gain the skill sets offered by their manufacturing courses [2][3].

For online delivery of the course content, instructors used reliable online learning solution systems like Moodle, D2L, and Canvas [4][5][6]. Numerous institutions have proven that these online learning management systems could provide the content and assessment tools needed by the course instructors to meet the instructional requirements.

Using remote laboratories and/or remotely accessible laboratories was another method practiced by some educators [7]. Some publishers and R&D organizations were able to develop virtual laboratories to help students gain hands-on exposure remotely [8].

Some remote communication platforms used by a high number of educators were ZOOM, TEAMS, and WebEx [9][10][11]. Several features offered by these systems include teleconferencing, chat, video sharing, recording, texting, teaming, cloud calling, and screen sharing.

Today, online instructional support materials conveniently available through several organizations and publishers have been used by many institutions and educators. The video components of these developments, called MOOCs (Massive Open Online Courses) [12], were the most commonly used components in the educational support category. Although the majority of them is commercially available through subscriptions from organizations like Tooling U-SME and LinkedIn Learning some of them, like YouTube, are freely available as long as internet

access is available. In the last decade, another practice commonly used by self-directed learners is through online learning sources like Coursera, and Udemy.

While many educational fields had great success using remote learning and digital education methods, there have been doubts about certain fields requiring hands-on education (like Manufacturing and Nursing). Learning about production methods i.e. Subtractive Manufacturing (SM) and Additive Manufacturing (AM) requires a lab component as students primarily learn through hands-on exercises. During the COVID-19 timeframe, this was a challenge because there were no existing platforms available for students to gain hands-on experience. One of the best solutions practiced by many educators was to give students an opportunity to virtually visit their laboratories through remotely accessible systems with the use of network cameras [13][14] [15].

In this case, production machinery would need to be set up before remote access was possible. A CNC machine, for example, would need machining bits to be installed in the proper toolheads prior to access by students. In a 3D printer, the filament would need to be replaced when the spool was empty. To remotely access the machinery, there had to be a reliable internet connection which was a challenge for some local internet service providers. Universities utilize VPN's for access to students and faculty to the university's network and can be extended to access the production machines as well. Typically, AM and SM machines have network connection features that make them easily accessible and machines without integrated network capabilities can be accessed by attaching them to a network-connected PC via USB.

As with any new process or technology, there are obstacles that accompany this approach to remote-access education. For 3D printing as an example, there are many prints that fail mid-print and 3D printed objects will need to be removed from the build platform every time it is finished. Researchers have developed methods to overcome these setbacks. Methods to detect print failure were developed and continue to improve. Machine learning or artificial intelligence [16] are being utilized for failure detection. Additionally, this new process has the added bonus of saving time, cost, and energy for remote and local printing. To release the 3D print from the build platform, for example, automated release mechanisms are being employed. One company [17] designed a build platform and a kit that auto-releases prints upon completion.

The goal of this paper is to provide a brief knowledge base about remote educational resources which are commonly used in instructing manufacturing courses and laboratory components. Composite Manufacturing (CM) is given as an example to show the availability of their current capabilities. Assessment and evaluation components of these resources are not the scope of this paper.

Tooling U-SME

Tooling U-SME, established as 'Tooling University' initially [18], is now owned by the Society of Manufacturing Engineers (SME) and is headquartered in Cleveland, Ohio [19]. It is a nonprofit blended learning ecosystem that provides a number of in-person and online learning solutions to organizations.

Today, a high number of Fortune 500 manufacturers and educational institutions chooses to use Tooling U-SME materials for their current educational needs and workforce development. Their programs are offered in different settings i.e. online classes, instructor-led training, customized solutions, certifications, and assessment tools [20]. Some courses offered are machining, maintenance, welding, smart manufacturing, composite processing, design for manufacturing, and post-processing. Figure 1 presents the Tooling U-SME online courses offered in CM.

Figure 1: Tooling U-SME CM courses offered in online settings

Several instructors using the Tooling U-SME resources in the past [21][22] have shown that the courses offered in the Flipped Classroom model result in higher student success rates. There have been a number of success stories resulting from incorporating this platform in high schools, community colleges, and universities. The availability of several web-accessible features and advantages of the Tooling U-SME system were cited by Schmidt as a significant asset throughout the COVID-19 years [23].

LinkedIn Learning

LinkedIn is one of the most commonly used business social networking sites used around the world, professionally-oriented to help users gain access to business, employment, networking, and career development opportunities. The site creates connections allowing job seekers to post resumes and employers to post jobs. LinkedIn launched on May 5th, 2003, and was acquired by Microsoft in December 2016 [24]. As of late last year, LinkedIn had 774+ million registered members from over 200 countries and territories [25][28].

LinkedIn Learning is a MOOC that provides a number of video courses delivered by subject matter experts in engineering, business, technology, and software tools all administered by

LinkedIn. The MOOC components are organized into three categories: Business, Creative, and Technology [26][27]. The remote learning platform was founded in 1995 by Lynda Weinman as Lynda.com before it was acquired by LinkedIn in 2015.

In a recent study conducted on Education Crisis, Workforce Preparedness, and COVID-19, it was shown that tools like LinkedIn Learning are a great solution for educators and students [28]. Figure 2 shows some of the available MOOC content in CM.

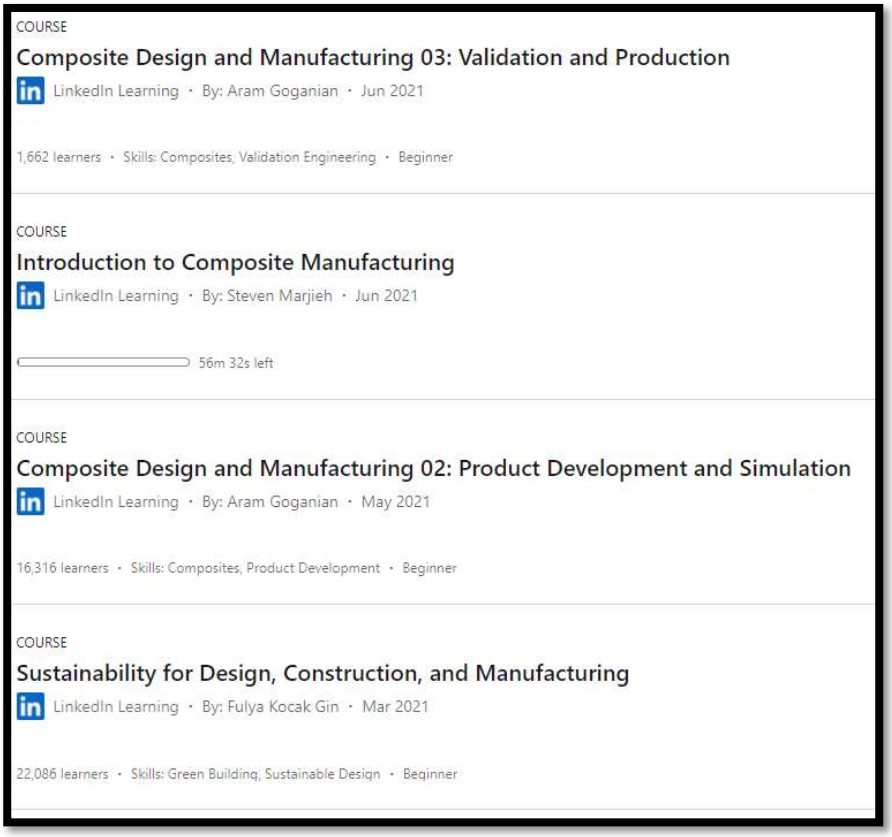

Figure 2: Some of the available CM content in LinkedIn Learning

YouTube

YouTube is the world's most commonly used online peer-to-peer video sharing platform owned and maintained by Google. It was established on February 14, 2005, and has more than one billion monthly users. The whole YouTube platform is freely available for users and has several versatile features like channels and live streaming [29]. The free video access is subsidized by advertisements.

Alternatively, YouTube has a subscription-based service referred to as 'Premium' and provides ad-free access to content across the service. YouTube content materials were successfully used in several courses and laboratories to support instruction and student learning as a supplementary teaching component.

In the last two years, several success stories of using YouTube in a virtual classroom setting and laboratory instructions were reported [30][31][32]. The resultant finding of YouTube-based learning indicates that YouTube is able to attract students' interest and reduce the time for students to grasp educational concepts. The use of YouTube-associated media makes learning active, creative, effective, and fun. Figure 3 presents a piece of YouTube screenshot for a CM search.

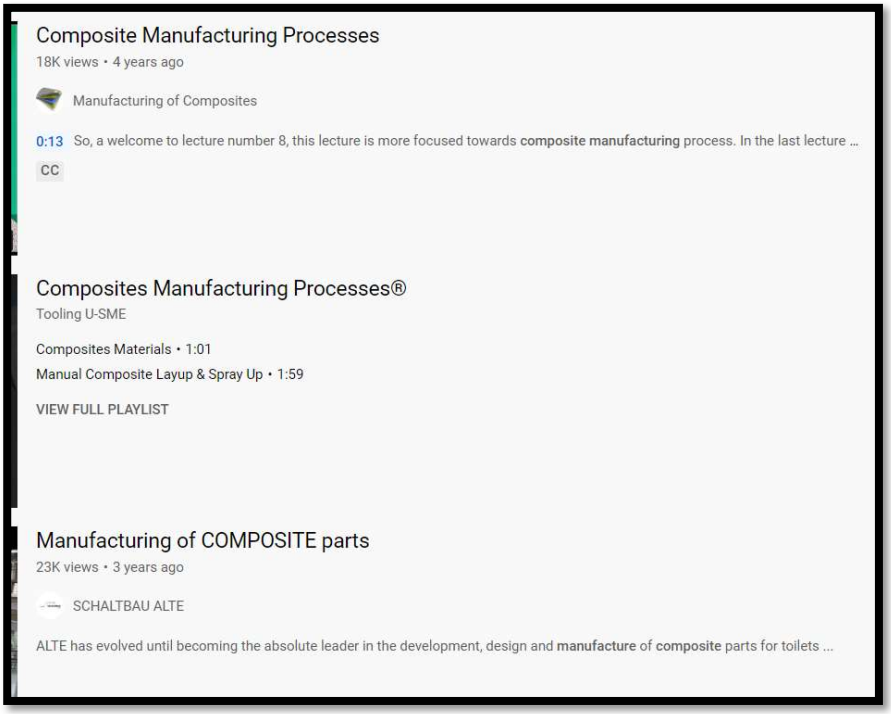

Figure 3: Snapshot of a CM search in YouTube

Coursera

Coursera is one of the most commonly used MOOC-based online learning providers established ten years ago by two Stanford University professors. This organization works with several universities to offer online courses, certifications, and degrees in a high number of subjects [33]. Coursera registered learners more than doubled after COVID-19 from 44 million to 92 million as of September 2021. Its database combines 4400 courses from more than 175 universities across the world [34].

Coursera classes generally last from 4 to 13 weeks offering free as well as paid content. The courses have assignments, weekly quizzes, and exercises to complete and the users can evaluate the quality of the courses. Additionally, discussion forums allow the students/learners to exchange ideas, increase social interaction, and post questions about the content of the lectures [35]. Figure 4 shows one of the CM classes currently available at Coursera [36].

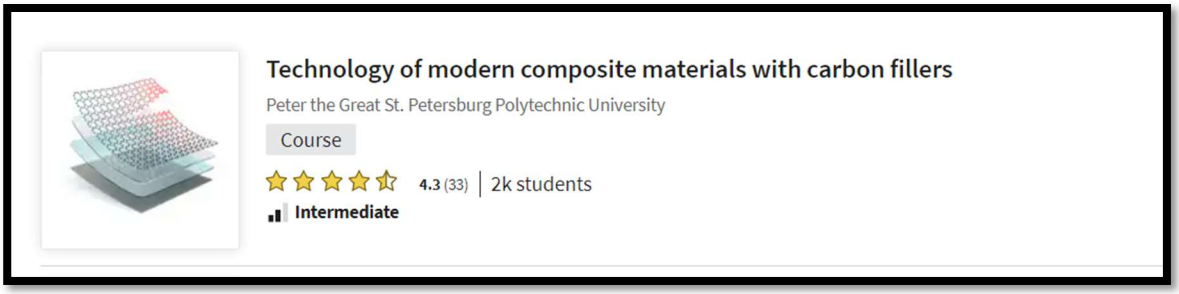

Figure 4: One of the CM classes offered by Coursera

The National Programme on Technology Enhanced Learning (NPTEL)

NPTEL was initiated by seven Indian Institutes of Technology and the Indian Institute of Science, Bangalore in 2003. This project is funded by the Ministry of Human Resource Development, a branch of the Indian government and is an online curriculum development program in sciences and engineering at university and research levels [37]. 235 courses in web/video format were developed considering five core disciplines: mechanical engineering, civil engineering, computer science and engineering, electronics and communication engineering, and electrical engineering. An additional 600 web video courses were created in major branches of engineering, and physical sciences at the undergraduate, and postgraduate levels and management courses at the postgraduate level [38].

NPTEL is the largest online repository in the world of courses in engineering, basic sciences, selected humanities, and social sciences subjects containing more than 56,000 hours of video content [38]. Access to the course material is free while the certification exam is optional and comes at a minimal course exam fee. NPTEL has also extended its work in initiatives such as laboratory workshops, internships, soft skills workshops for improving employability, and other non-technical classes. Figures 5 and 6 present some of the latest courses offered in AM and CM.

Figure 5: Course offered on NPTEL–Fundamentals of AM Technologies

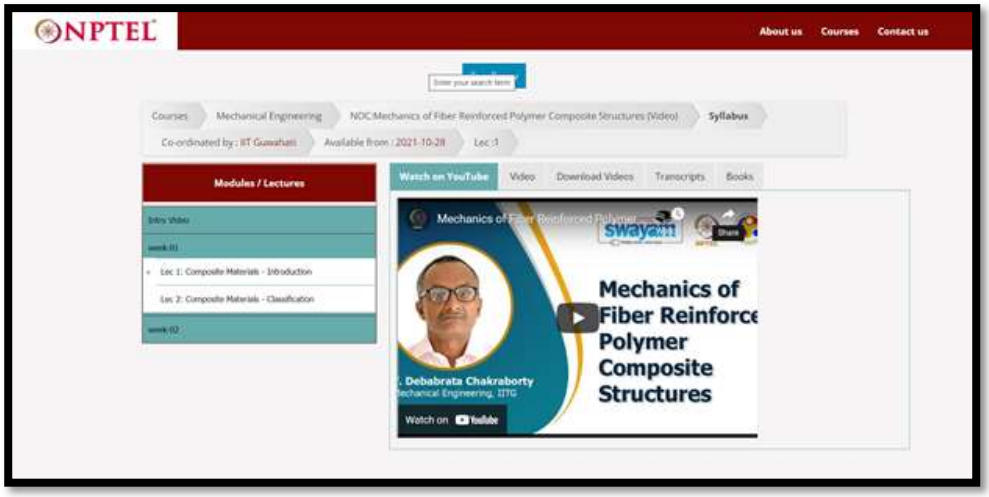

Figure 6: Course offered on NPTEL–Mechanics of Fiber Reinforced Polymer Composite Structures

Udemy

As several universities were shuttered because of the COVID-19 pandemic, digital platforms such as Udemy have played a critical role in assisting students in progressing in their education by offering online lectures, materials, chat, and teacher engagement all in one site [39][41].

Udemy created a learning ecosystem that allows teachers to upload videos, PDFs, and PowerPoint presentations so that students can access high-quality resources at any time. This includes virtual real-time classes in which a group of students participates. It gives students and teachers the opportunity to ask questions and have them answered right away. If students are unable to attend during the specified class time, they can view previously recorded lecture videos. Udemy provides courses in a variety of subjects such as Art, Business, Health Science, Music, Language, Entrepreneurship, and technology, among others [40].

Udemy has further subdivided the videos covering Manufacturing related courses into subcategories such as Engineering, Industry, and Management. The videos are offered in 0-1hr, 1-3hr, or 3-6hr durations. Students can also select from Beginner, All Levels, Intermediate, and Expert material/class difficulty. The site also includes subtitles, quizzes, coding activities, and practice tests to increase student engagement and evaluation [41]. Figure 7 shows the list of available CM instructions [42].

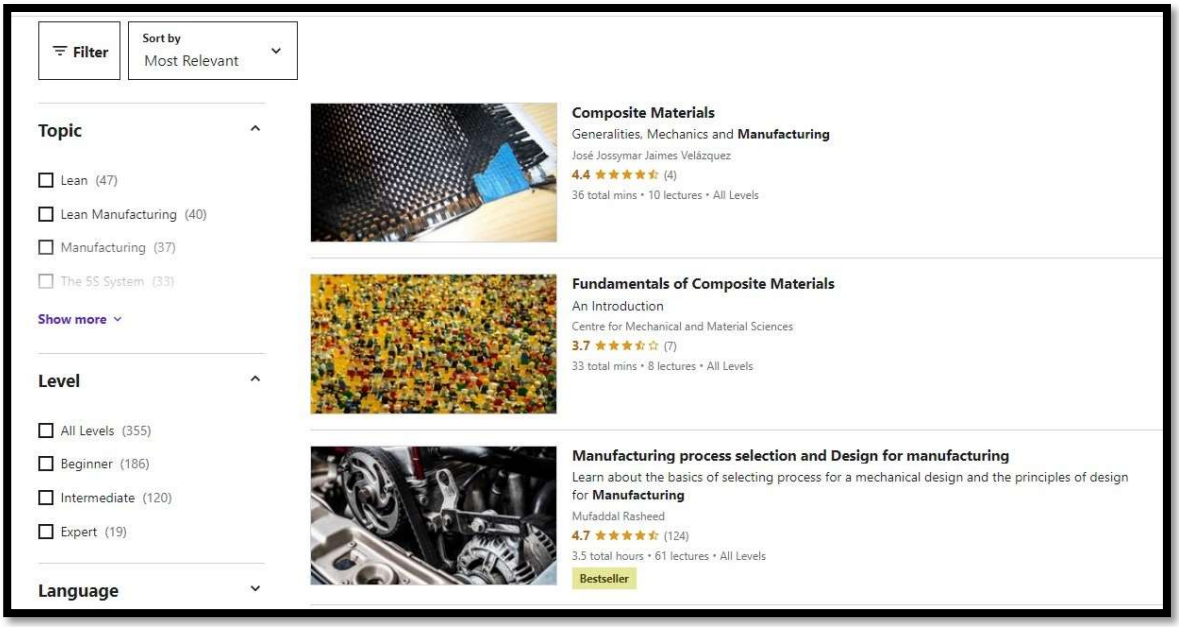

Figure 7: Current CM courses listed at Udemy

Conclusion

This paper reports the most commonly used web-based learning ecosystems by manufacturing educators and students. The knowledge blocks covered by this paper were collected by a diverse group of educators who hold positions in educational organizations. CM was provided as an example in searching the capabilities of these systems but it is clear that the platforms reported here contain a high number of topics in current advanced manufacturing practices. In the future, the plan is to add more information from the practitioners of these systems with a qualitative and quantitative survey tool.

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