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Work in Progress: Post-Pandemic Opportunities to Re-Engineer Engineering Education: A Pragmatic-Futurist Framework

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I am a lifelong transformer. My personal, educational journey has built my skills as an engineer, leader, collaborator, and communicator. My education, engineering problem-solving skills and entrepreneurial spirit have naturally pushed me toward need-based innovation. The global pandemic has exacerbated societal problems and inequality and heightened the necessity of need-based innovation in many areas. One significant area is education. My goal is to leverage my skills to deliver innovative solutions for the Future of Education.

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Abstract

In the context of the COVID-19 pandemic, education has stepped up some of its long-overdue transformations. Higher education (HE) and Engineering Education (E.E.), particularly, is facing a potential crisis. Engineering schools and professional societies are dealing with several pressing problems that potentially threaten their survival. Although E.E. leaders are bound to focus on short-term survival, sustainable growth and development in the long term must also feature in the agenda. In this work, the context of disruption in the education domain is revisited through a literature review, related threats and opportunities are identified, and a strategic way forward is investigated in those lights from Engineering Education's perspective to inform a pragmatic futurist's perspective. A needs-driven innovation model (why-what-how approach) is pursued to present the study where the shift in mindset, changes in infrastructure, and leveraging digital technologies emerged as the central concepts. Each of those broad implementation categories encompassed various subsequent initiatives such as a life-long learner's mindset, a focus on how-to-learn, a strong emphasis on professional skill development, industry-academia alliances, a reflective broadening of engineers' considerations, and extensive opportunities for multi-disciplinary collaboration. To this end, we propose a pragmatic futuristic framework for accessible access to affordable, relevant, and personalized education for learners, faculty, and institutions from all diverse backgrounds. The new framework encourages fresh relationships among the key actors in the context of new modalities for the transfer and co-creation of knowledge, requirements, and possibilities for change in operational models and tapping into the boundary-breaking opportunities fostered by digital ways of teaching and learning. This study aims to provide a future-proof pathway for the engineering education ecosystem to better equip it for solving real-world problems with a multi-disciplinary approach to create new value for society. In the process, the study also sheds light on relevant new research avenues.

1. Introduction

Needs-driven innovation (also known as needs-based innovation) has been in use in the field of Bio-design for nearly 20 years now. [1]. One of these innovation techniques is framed through a 'why or what and how' approach by Kate Rosenbluth [2]. This approach starts with observing the unmet needs of the system and takes a very objective approach to screen these needs. This is a dynamic process where the journey from the need to its solution is much more a circle than a starting point. The groundwork for progress is not primarily about the invention or the solution, it is carefully laid and takes a deep understanding of the needs. The building or advancement of an institution is grounded in understanding the 'Why' through a strategic framework. The global COVID-19 pandemic has exacerbated societal problems and inequality and heightened the necessity of innovation in many areas, including education. The goal of this study is to apply the strategic framework of the needs-driven innovation model to re-engineer higher education in the context of engineering professionals. We propose a pragmatic futuristic framework for accessible access to affordable, relevant, and personalized learning in the education ecosystem (including learners, faculty, and institutions) from all diverse backgrounds.

History has shown that a global event often instigates major shifts in how we perceive things and drives us to build something better than what existed previously. The integration of women in the workforce during and after the Second World War [3] and the formation of the Truman Commission [4] are two such examples. The latter deserves a deeper look for its intimate relevance to this work on higher education. It was a historic and unprecedented leadership move by U.S. President Harry Truman to assemble a group of 30 education and civic leaders to soul-search the purpose of higher education. The result was a report on Higher Education for American Democracy, commonly known as the Truman Commission Report or simply the Truman Report. It was produced in six volumes, and its recommendations focused on three key areas: improving college access and equity, expanding the role of community colleges and restructuring and expanding federal funding on higher education. The report provided ten sweeping recommendations[4], several of which addressed the goal of increasing college attendance and enrollment. Although its proposed actions did not all happen within the envisioned time frames of the Commission, and some may never be implemented, the majority of the recommendations have come to fruition. This initiative was expected to make higher education democratic, where everyone had a fair chance at educating themselves without financial or any other constraints. This vision is not yet fully realized, and the situation has shifted in a new direction in recent times.

In 2020, after the exponential outbreak of the COVID-19 pandemic, United States once again prepared to rebuild its leadership in world affairs. The pandemic forced almost every aspect of our lives to shift to online modalities, including education. This crisis has accelerated the urgency for renovation in the education sector. The needs of the customers of the post-COVID world are significantly different from any analogous time in history. This is a call for the re-examination of the purpose of higher education and requires reinvention in the education domain, putting the customer (learners) at the center of care. Higher education (HE) has stepped up some of its long-overdue transformations in recent decades. Institutions were dealing with several pressing short and long-term issues even before the pandemic. The affordability of higher education, the value of a 4-year college degree, and the relevance of conventional education in this 21st century have already been in interrogation for a while [1-5]. At the same time, a new generation of digital technologies has matured and can now be deployed at scale. This new generation of digital technologies, including Artificial Intelligence (A.I.), Augmented Reality (A.R.), Virtual Reality (V.R.), cloud computing, machine learning, mobile technologies, etc., has evolved and will continue to advance in the future. This has created the opportunity to provide personalized and customized education online at a much more affordable price compared to the conventional system of education. Digital technology has revolutionized many industries so far and can make substantial transformations in the education domain.

While online education has been available for several decades, the pandemic effectively eliminated the psychological barrier to change for all the stakeholders (institutions, faculty, and learners). This established the digital way of learning as a mainstream system for education, leaving it as the only alternative that forced the faculty and students to adapt to the digital in a short time. Most faculty and students transferred to remote education within one to two weeks' notice. It accelerated the educators to adopt digital fluency, and students created new habits of

learning through distant lectures with all its limitations and certain advantages. With a sudden surge in customers, the application providers stepped up to improve their software solutions, creating wide acceptance, and lowering the psychological barriers to change among the institutional leaders, faculty members, students, parents, employers, and service providers (such as content creators and education technology platforms). The COVID-19 pandemic has forced global experimentation with distance education all over the world.

When such unexpected events force widespread experimentation around a new idea, this frequently results in lasting changes. At the same time, the obligatory shift to remote learning resulted in significant measures of teacher burnout, stressed parents and students, and mental health issues associated with student motivation and isolation. Moving forward, ways of maintaining the momentum towards a digital classroom need to factor in the social, cultural, psychological, and affective needs of students and teachers.

In this paper, the needs for change in higher education in a post-pandemic world are addressed under the assumption that digital technologies will remain a mainstay after their accelerated adoption during the COVID-19 pandemic. We have undertaken a why-what-how approach to call for needs-driven innovation in education, like why there is a need for change (the need), what is the recommendation (the solution) and how those could be implemented (the plan). We introduce a strategic framework for how engineering institutions, faculty, and students must start considering their options, experimenting with alternatives, and start planning now. A shift in the mindset, leverage digital technologies, and change in the structure are taken as the central ideas leading to solutions to the identified problems themselves and affecting the long-term goals of accessible access to affordable, relevant, and personalized education that fits the need of diverse groups of learners.

2. Why: Pressing Issues in Higher Education (HE)

Existing short- and long-term issues in higher education have potentially threatened its survival for a while now. The major issues demanding rigorous reform inside education are highlighted in this section.

2.1 Affordability

One of the major issues in higher education today is a large population does not have access to quality education at an affordable price. The number of students receiving a 4-year college degree is comparatively low. According to the U.S. Department of Education, the gross enrollment ratio (GER) in the USA is 70%, which means 70% of the students who graduated from a high school enter a 4-year college. Among them, about 60%, students complete the degree. This indicates around 40% of the U.S. population receives a college degree [5]. There is also an ongoing financial strain on the American higher education system. In the last 20 years, there has been a systematic reduction in public higher education funding, which has been the driver of socio-economic mobility in this country (80% of the students go through the public higher education system) [6]. There has been a funding reduction of around 30% per student in public higher education since 2000 [7].

The cost of higher education has seen an astronomical rise in the last 30-40 years. Today a 4-year college degree will cost anywhere from $250K-$300k. According to the U.S. Bureau of Labor

Statistics, tuition fees have increased by more than 1184% in the last 40 years [8]. This likely makes higher education one of the fastest-growing commodities in terms of price, as there is no good, product, or service that has grown in price to this degree in the last 40 years. Student debt has also reached unacceptable levels, leading to a public outcry in America. Data shows that student debt has steadily increased in the past ten years, nearly doubling to an all-time high of 1.7 trillion dollars in America in 2020 [9]. This indicates the education cost is beyond reach for a large population.

2.2 Perceptions of Relevance

The value and relevancy of a 4-year college degree have been in interrogation for a while now. In decades past, a 4-year degree nearly guaranteed the recipient would get a job in their particular field. Now the situation is different because there are more people with degrees, jobs require higher qualifications, and the world is rapidly changing. According to the U.S. Bureau of the Census, in 2010, only 27% of Americans were using what they studied in universities; thus, most students are likely to work in a job not directly related to their major. The same census data showed that roughly 60% of the U.S. college graduates were working in fields where their degree was not required [10]. There is certainly some transfer of learning to related areas; however, research has shown that transfer of learning is not nearly as general as expected. This raises questions of how education needs to change to make it more effective, productive, and relevant to the need of the learners. [11].

Correspondingly, the job market scenario is also changing rapidly, and it is difficult to predict what the job market may look like for engineers in 20-30 years. With the accelerating growth in technology, the world is changing so rapidly that many of the top jobs today were not available as college degrees just ten years ago (for example, Virtual Assistant, App Developer, Web Analyst, Big Data Analysis, etc.). Many students may not be directly using content they have learned in the classroom. Additionally, only 42% of employers in the United States believe that graduates are adequately prepared for the workplace [12], and 53.6% of graduates are unemployed or underemployed [13]. The country appears rife with an overqualified population having expertise that does not correlate with industry perceptions of real-world needs.

There appears to be a skill gap between what is taught in university and what makes people valuable in the industry. In 2015 one of the most esteemed accounting firms in the world, Ernst & Young, dropped degree requirement from entry criteria in their department of human resource (H.R.) after finding 'no evidence that success in higher education correlates to a successful career or building a successful life [14]. High-tech companies like Tesla, Google, IBM, Microsoft, Apple, and Facebook are declaring the same [15, 16]. This indicates that somewhere along the line, there is a gap between what students are learning within the four walls of a university and what is required when students step up into the workforce.

Some readers may question the implicit assumption in the previous paragraphs that the main (and perhaps only) purpose of education is to serve the industry. Such practical matters are surely important, and salary expectations upon graduation often influence student motivations for attending college and choices of major. However, if education becomes merely the servant of industry, then our society has much to lose. Industry, driven by free-market economics, has historically proven itself to be a poor steward of natural resources and quite willing to ignore the environment upon which life on this planet depends. Furthermore, we risk losing important knowledge, skills, and abilities that make society a richer and more enjoyable place when we

focus purely on economic gain and neglect the pursuit of the arts and humanities for not being economically profitable. The learning of ethics and values, the capacity for reflection, the skills of creating and maintaining democracy for a fair and just society all depend on learning that may not be marketable in today's economy. Still, without them, our future looks bleak. Many people agree that the purpose of a college education transcends mere training for a job [17]; however, post-graduation employment opportunities clearly motivate many people to attend universities, and perceptions of irrelevance may drive them away.

2.3 Personalization

Higher education today is rarely personalized to the needs of the learner. The call to "advance personal learning" is recognized by the National Academy of Engineering (NAE) as one of its Grand Challenges for Engineering [18]. Traditionally, the education system has followed a one-size-fits-all approach to learning and development, where a single set of instructions is delivered to all regardless of variation in the interest, strength, or optimal learning method of an individual. This rigidity ignores differences in age, background, motivation, and profession. Every individual and his or her brain work differently, which certainly affects learning effectiveness. The information processing mechanisms, strengths, and weaknesses vary from one individual to another. While one student can grasp the information well through traditional classroom lectures, another individual might better understand the same topic when delivered through audio-visual multimedia. The interest for the topic, the attention depth at that moment, the style and method of delivery are a few among many things that could be relevant for attaining maximum possible effectiveness through personalized learning.

3. Why Now: Impacts of the Pandemic

3.1 Pandemic as a Driving Force for Change

Humans are often resistant to change. In the last two decades, despite the visible rise and availability of online educational resources, we have perhaps overlooked the relevant but uncomfortable question of whether that should challenge the status quo and replace some of the age-old practices. The pandemic-driven online modalities forced us to face that question and live by new rules. While societal changes of this order usually take a very long time for a full transition due to mental, bureaucratic, and economic barriers, in this case, the pandemic has potentially accelerated this transition.

As we had to embrace the digital way of teaching and learning, it also brought some of the difficult questions about education to the surface. From different angles, different key stakeholders of the learning ecosystem had a chance to soul-search the taken-for-granted conventions and face questions like:

- If teaching and learning can be effectively done without the expensive physical setup of college classrooms, why should someone pay so much for a formal college education?
- Suppose video lectures from an instructor at a little-known university are to be developed and viewed online. Why would students choose those rather than view the free lectures available on the same topic from a famous professor at a more prominent university?
- Why does someone have to compete for a coveted seat in a popular course when delivering things online can overcome that physical limitation?

- If a school does not prepare us well for the biggest problems facing humanity, such as this pandemic itself, how worthwhile it is to spend prime years of youth in school and then carry the burden of long-term financial debt for that education?
- Taking notes from the classroom whiteboard and borrowing books from the college library are no longer the only major ways to access the knowledge materials, so why pay more for those facilities?
- After the pandemic is over, is it best to get back to the pre-pandemic status-quo, or will there be better alternatives discovered through the pandemic experience?

3.2 Challenges for Access and Equity

In addition to prompting reflection about the need to lower the cost and increase the efficiency of education, the pandemic has also illuminated and exacerbated existing problems and challenges associated with online education that will need to be considered and addressed. For example, a September 2020 report of the Economic Policy Institute [19] drew attention to many issues of access and equity for online teaching and learning in K-12 education that is coming to light. Adapting these concerns to higher education in general and through the lens of our own observations and experiences in engineering education during the pandemic in particular, the following issues and questions emerge:

- A digital divide exists that creates barriers to learning for many due to differences in wealth and infrastructure. How can online education and associated infrastructure be improved to benefit all students, rather than just those who already have or can easily afford reliable, high-speed Internet access and new computers capable of utilizing high bandwidth? How might students, faculty, and institutions best encourage and support the investments and political willpower necessary for inclusive access?
- Assessment in online education is challenging. Will multiple-choice tests that reward only a narrow skill-set prevail? How might assessment choices serve to limit learning or privilege some ways of thinking and knowledge over others? How can assessment of online education be improved to better encourage breadth and depth of learning?
- Student engagement, sense of belonging, and social needs are difficult to support through online education. How can these aspects be improved to limit disengagement and attrition that may disproportionately affect marginalized groups?

Equity and access have long been issues in higher education, and as mentioned in the Introduction, the COVID-19 pandemic is not the first event of a global impact to catalyze change. Immediately following World War II, Truman Commission Report recommended widespread changes in higher education, including "the elimination of racial and religious discrimination," "the integration of vocational and liberal education," "the extension of free public education through the first two years of college for all youth who can profit from such education," and "the doubling of college attendance" [4]. The report further urged the establishment of community colleges by re-conceptualizing "junior colleges" with a broader and more locally integrated purpose [20], and it recognized the need for Federal financial support to ensure "that the poorer States can bring their educational systems closer to the quality of the wealthier States" [4]. Though improvements have been made, some of the challenges faced by

the Truman Commission remain the same today, and we would be wise to learn from both the successes and failures that have occurred in the nearly 75 years since its release. This is a topic for future work that is beyond the scope of this paper.

4. What and How: Opportunities for Engineers to Re-engineer Higher Education

The COVID-19 pandemic has accelerated the adaptation of online education as a mainstream delivery model. This is a moment university leaders need to seize. With the fair assumption of the disruptions taking place in the education domain (mostly leveraging the distant/remote knowledge transfer mode), there are some potentially impactful opportunities to be pursued in Engineering Education. Engineers can leverage digital technologies, not only as learners but also as knowledge providers, to transform the learning experience. We provide a strategic framework for how engineering institutions, faculty, and students can influence the long-term goals of a sustainable, reformed engineering education system through a shift in mindset, leveraging digital technologies, and making changes in the structure. These are outlined in Table 1 and Figure 1 below and then described in more detail in the paragraphs that follow.

Table 1: Needs-Driven Innovation Model for Education

Why? (The need for change)	Affordability	Relevance	Personalization
What? (The Solution)	A Pragmatic Futuristic Framework		
How? (The Plan)	***A shift in mindset***	***Leverage digital technologies***	***Changes in infrastructure***
Institution	Choose a future-oriented pathway	Invest in and build I.T. infrastructure	Provide training for faculty and students
Faculty	Focus on teaching how-to learn	Use the power of digital resources for knowledge transfer	Engage in multi-disciplinary collaboration
Learners (Students & Professionals)	Adopt practices of lifelong learning	Seek unbundling options	Engage in professional skill development

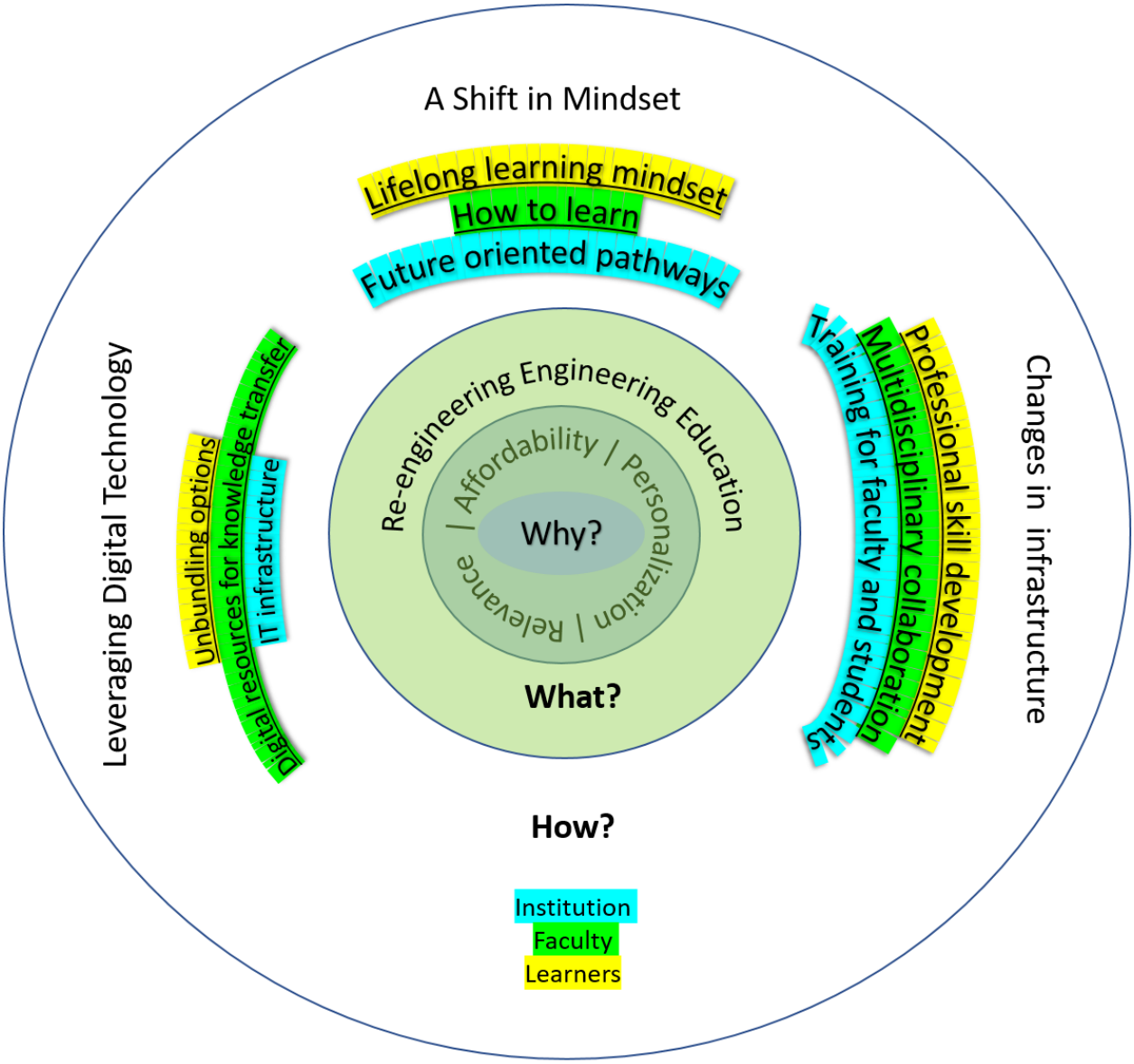

Figure 1: A Graphical Representation of the Proposed Framework.

4.1 A Shift in Mindset

4.1.1 Institutions: A Future-Oriented Pathway

The pandemic and the subsequent economic downturn have forced institutions to deal with some pressing short-term issues. However, this is also an opportunity for universities to consider long-term strategic issues. Education leaders have this unique proposition of using the data from the currently forced experimental setup of online learning with which to design scaled pilots to

discover sustainable models for future higher education. This requires a shift in mindset. Recent work from Vijay Govindarajan and Anup Srivastava offers an agenda for how universities can choose a point of view among the following three paths paraphrased below [21]:

Path 1: Augmented Residential Program

This is the gold standard of the 4-year residential college experience. Although colleges can be improved in many ways, they still provide a safe and healthy way for students to transition to their careers. Students setting out for college campuses, getting out of the comfort of the family for the first time in life is itself a giant leap in their maturing. Then the experiential learning coming from open discussions, making deep, meaningful connections, and dispute management in classes and dorms all significantly contribute to shaping them as responsible future citizens. Students learn not only from the faculty but from their peers. They learn about themselves, their identities, their interest, their character, school pride, conflict resolution, emotional intelligence, and a whole host of things. However, even with all its benefits, this residential experience is not accessible to all groups of students due to its high price tag. It is, therefore, an opportunity to soul-search the traditional models and investigate whether the new digital capabilities can complement the conventional model leveraging the existing infrastructures. In any case, this four-year residential model of a college degree should not be the only choice for students in today's digital era.

Path 2: Hybrid Model

The current scenario of online teaching enables the university to consider substituting, complementing, or augmenting the courses, leveraging their real-time data on how digital media impacts certain aspects of the courses. With some components of the courses offered digitally, it can potentially be scaled up with a minimal incremental cost. Courses that are pure knowledge transfer, with little or no interaction with students, could migrate online. For lab/project-based courses, students and faculty need to come together. Universities now have some data to find the optimum mix of face-to-face, real-time virtual, and asynchronous virtual instruction modes for each course. This might enable the programs to be designed with more flexibility than a strict four-year timeline.

When the conventions are challenged and the four-year college degree is reformed, there is also an opportunity to redesign the learning pathway with competency-based programs and a stronger industry-academia alliance. In this new modality, engineering students may attain industry attachment from early-career instead of committing to four straight years in college (example: Northeastern University). Thus, academia can flexibly evolve with the technological changes ruling the business world, and students will likely be able to relate their classroom and lab learnings more with the job responsibility space. Spending half of the year in academia will then be guided and rewarded by the industry engagements before and after, as the online course materials are flexibly spanned across the work and study commitments in a self-paced timeline. This will induce a lifelong learning culture across the whole employer-employee-student-teacher ecosystem. This long-term co-op or industry attachment will also encourage intrapreneurship (i.e., entrepreneur behavior while working within a large company) among students and will create new entrepreneurial values. This can be facilitated by the course unbundling options created by online teaching/learning repositories, as various learning tracks can be designed. Universities can employ competency-based programs on a large scale (e.g., four courses in machine learning, six courses in creative writing) for students who require the necessary skills.

The hybrid model has the potential to make education affordable to a large group of students. Note, however, that teaching hybrid courses requires hardware/technology not found in all classrooms and creates considerable burden and overhead for instructors.

Path 3: Full Online Model

Many high school students directly go to work at minimum wage and never get the opportunity to attain a residential college as they cannot afford to leave their job for that experience. It does not imply that they do not need high-quality education. There is a demand for good quality education from reputed universities at an affordable cost. Since asynchronous online learning scales at near-zero incremental cost, the universities may orchestrate innovative models catering to high quality at low cost. While the conventional trend is vertical integration with in-house capabilities, in the context of online education, many of the functions like content creation and integrating augmented and virtual realities may be outsourced to ecosystem partners specialized in the tasks. This will further reduce cost and attain scalability.

The Full Online Model also has the potential to reach a much wider swath of the national population and perhaps even internationally. In principle, if online tuition costs are kept low and/or adjusted based on financial need, this could help to address some of the issues of access and equity mentioned above, similar to the way the community colleges initiated by the Truman Commission Report have helped bring higher education in reach for many who would otherwise end their educations early.

Another potential benefit for the Full Online Model is the support it can provide to learners who are differently-abled, such as those affected by limitations of vision, hearing, speech, movement, learning, and/or cognition. By following guidelines for accessible online course design like those applicable from the Web Accessibility Content Guidelines 2.0, online courses can better support not only the differently-abled but general users as well [22].

4.1.2 Faculty: Focus on Teaching How-to-learn

By now, the teaching faculty must have realized that obtaining sources of information is no longer a challenge. Therefore, access to 'what to learn' has become a minor factor and is no longer the selling proposition of educational institutions, or the faculty for that matter. However, there is now a need to teach students to critically evaluate and vet the information they find and use. Although the information is much more easily available, it is not always of the same quality, accuracy, and validity. Learning how to distinguish false, inaccurate, or even agenda-driven information is an important skill to teach and learn.

Additionally, the university faculty themselves are the most successful story of life-long learning and transformation, and that is where they can add much value in creating the life-long learners of the future. It is imperative that, given the fast-paced world, every learner in engineering education will be in constant need of learning new things during and beyond school and work. The faculty, therefore, need to position themselves as the advocate and model for students to teach them how to learn instead of what to learn. The online modality of knowledge transfer would leave extra time for faculty to focus more on that 'how to learn' aspect. They can spend that time collaborating across disciplines, designing real-world problem-solving challenges, and conducting one-to-one sessions with students for personalized mentoring to inspire them to be lifelong learners.

4.1.3 Learners: Adopt Practices of Lifelong Learning

There is no longer the need for a partition between 4 years of college education and the rest of the years in work life. We need to adopt a mindset of lifelong learning. With the fast pace of today's technology-driven world, we are increasingly in a scenario where the technical, subject-matter skills taught in a 4-year college degree are likely to become less important unless they are continuously renewed. This phenomenon is profoundly different from the core idea on which the existing education system was formed nearly hundreds of years back. Only twenty years back, it was possible to predict that a computer scientist with his/her basic software development skills would have a secure job-life for decades. If we look at today's job market, computer scientists are working in roles that demand expertise in augmented and virtual reality, artificial intelligence, data science, business analytics, decision science, and so forth. Almost all these roles are beyond the existing structural framework the conventional college degrees offer, and therefore, students are only best fit for such roles when they practice a life-long-learner mindset. While the access to learning materials and relevant information is no longer confined to the classrooms and libraries of colleges, it would still take a learner to exercise that continuous-growth mindset to leverage the boundless opportunities of a connected, digital world.

Figure 2: *Ikigai* (Reason for being) [23].

A self-study path for an individual learner can follow the course of '*ikigai*,' a Japanese word that roughly translates into the 'reason for being.' This is a lifestyle that strives to balance the spiritual with the practical. It is a purpose-driven career approach that starts with the 'why' of every individual. Starting with why is significant to ignite the passion of each individual and go forward despite uncertainty and limited resources [24]. As illustrated in Figure 2, the balance is found at the intersection of one's strengths, interests, and passions with the needs of the world [23]. When student's learning curricula are based on their strengths and interests, it is most likely that they will succeed in their professional life and engage in roles that satisfy them the most. In

the process, learners will educate and equip themselves with the tools that truly needed to live a quality life and make a meaningful impact on the planet.

4.2 Leverage Digital Technologies

4.2.1 Institutions: Invest-in and Build IT-Infrastructure

The shift to a predominantly online modality of education comes with added hardware-software infrastructure requirements for institutions. While they would benefit from the scalability of digital technologies like mobile, cloud, and A.I., there is significant work to be done to get the infrastructure ready to turn the digital ways into the de facto model. However, issues like access to the Internet, availability of bandwidth, ownership of suitable electronic devices are then integral factors across multiple stakeholders and bring on the concerns of the digital divide. The digital divide also exists among the universities themselves, where some well-funded private universities already boast a much stronger I.T. infrastructure than others. So, a common minimum standard must be defined and reached across the digital ecosystem to deliver online education seamlessly, overcoming the digital divide and technical limitations. The organizational focus, structure, and personnel ratio must be redefined to implement such strategies.

4.2.2 Faculty: Use the Power of Digital Resources for Knowledge Transfer

Faculty at universities are generally involved in three things: knowledge transfer, co-creation of knowledge, and developing AI-resistant capabilities. Faculty members can use the power of digital technologies to improve the learning experience. They can use technologies to substitute the knowledge transfer part of a course, such as by pre-recording lectures (asynchronously), bringing guest lecturers virtually (maybe an executive from Silicon Valley), and many more. Simultaneously, they can utilize the in-person experience for knowledge-cocreation and develop AI-resistant capabilities, such as judgment, creativity, connecting the dots in a complex set of variables, perseverance, emotional intelligence, etc. They can also use more of their time for individual care: advising, counseling, teamwork, etc.

As an indicative example, animation and graphics can be used through a software application to teach the physical concepts of force, moment, and equilibrium; the online modes also allow students to learn at their own pace, repeatedly view the sessions if needed, linking the key concepts and have customized organization of courses depending on their sequential progress and interest. Learning topics of science and engineering, however, would in most cases require hands-on lab experience, while courses like Egyptology and Social Media, which depend on group discussion, could be taught using virtual meetings.

4.2.3 Learners: Seek Unbundling Options using Digital Technologies

Higher education generally follows a vertically integrated model where everything is done in-house, from the admission of new students to awarding their degrees. Due in part to its structure, the cost of education keeps rising. Students, as customers, can seek unbundling options in higher education, such as competency-based programs and co-op opportunities. This demand will create an essential market. Consider a case where a person is planning to listen to his favorite music on a journey, and his choice of songs is from six different albums. Due to unbundling opportunities in the music industry, that person does not need to go through the trouble and costs of buying six different C.D.s for that purpose, and rather he can compile all the music needed into one CD. Similarly, a student or professional interested in learning a new topic/skill from different

institutes or educators may have to go through the rigid educational system and suffer mentally and financially. This contrast may seem to have no parallels; however, the gap between institution offerings and student needs has the potential to shape both industries the same way. Due to the changing landscape of the job market and the new generation of students, the future of education will demand more unbundling options. Digital technology has enormous potential to make these changes, and students should begin asking for them while also keeping in mind that utilizing such an "a la carte" learning method may need to be guided by an advisory group of faculty and industry representatives from a variety of backgrounds.

4.3 Changes in infrastructure

4.3.1 Institution: Provide Training for Faculty and Students

This moment creates the opportunity for all the stakeholders, including faculty and students, to train themselves to get on board with the new ways of the digital era. While the faculty include people from different generations, and some of them shy away from the virtual means, this is high time that an integrated strategy is taken to bring them on the same page with younger faculty and the tech-savvy generations of young students. Combining their experience and wisdom with technological capabilities, we can expect to find new ways of developing and delivering education with better results. This would also make them think about the possibilities that cannot be confined by the physical border of a classroom setting; greater collaboration, multi-disciplinary engagement, real-world problem solving, industry attachments, to name a few.

Students must also be trained to get the most out of the online experience. It is observed that lower attention span, multitasking, other distractions are common in online learning mode. Retaining the motivation and self-drive to choose, start and finish a course are often challenging for them. A whole new mindset needs to be trained so students can overcome the issues and benefit from the freedom and flexibility of online learning without compromising the guaranteed advantages of face-to-face teaching.

4.3.2 Faculty: Engage in Multi-disciplinary Collaboration

Taking education beyond the walls of the classroom can unlock many new avenues for engineering education. It will enable a fresh multi-disciplinary approach towards real-world problem solving by redesigning programs, courses, and projects. Let us take a scenario where a multi-disciplinary project team consisting of students from engineering, life science, economics, sociology, agriculture, business, supply-chain management, history, and the arts are tasked with designing a global campaign for climate change issues. The end-to-end critical thinking, coordination, communication, design aspects, problem-solving, and leadership involved in this approach may be able to provide the boost in professional skill development engineering education had been lacking. Engineers are expected to play a leading role in such courses or projects because technology plays a central role in modern-day problem-solving. This would also encourage engineering education to emphasize societal value creation, and the students will find purpose in their studentship and career. People who come from widely diverse backgrounds and can bridge between generations and cultural backgrounds will need to build a culture of respect that actually welcomes, celebrates, and builds on people bringing their best selves to work together.

4.3.3 Learners: Prioritize Professional Skill Development

Work placement (internship) experience from students and employers reveals that many students are not ready for the required level of thinking, complex problem solving, level of conversations, and the output required in the workplace environment. According to LinkedIn's recent Global Talent Trends report, 92% of talent acquisition professionals reported that professional skills are equally or more important to hire for than technical skills and, 89% said that when a new hire does not work out, it is because they lack professional skills [25]. Table 3 provides a list of the top 10 skills of 2025 by the World Economic Forum [26].

Table 3: Relevant Professional Skills for the Future

Type	**Skill**
Problem-solving	Analytical thinking and innovation
	Complex problem solving
	Critical thinking and analysis
	Creativity and originality
	Reasoning, problem-solving, and ideation
Working with people	Leadership and social influence
Self-management	Active learning and learning strategies
	Resilience, stress tolerance, and flexibility
Technology use and development	Technology use, monitoring, and control
	Technology design and programming

Engineers of today's world desperately need to build AI-resistant capabilities since it is hard to predict what the job sector would look like for the 2030 workforce. Engineers, therefore, need to develop a new set of transferrable professional skills that leverage creativity, critical thinking, cross-disciplinary innovation, leadership, and entrepreneurship. To address the most pressing problems of the modern world, engineers need to associate with various other disciplines. They would have to apply a whole range of professional skills, including leadership, communication, interpersonal relationships, and decision-making. In the post-pandemic world, engineers will have an opportunity to exercise the new digital paradigm for engineering education. In the digital mode, the brick wall of the classrooms does not confine engineers. Engineers can be given real-world problems for which they will have to collaborate with people from other disciplines. Such problem-solving engagements will promote the whole-person skills and professional development of engineers. The challenge, however, is to ensure that effective learning of professional skills like ethics, social intelligence, etc., are not impeded by the use of digital educational technologies.

4.4 Prioritization Strategy

As various change initiatives with their related stakeholders (institution, faculty, and learners) have been identified, the potential positive impact and their difficulty of implementation are expected to vary in different institution-faculty-learner settings. Hence, there is hardly a generalized definitive method to rank or prioritize the initiatives. However, the decision-makers can follow a two-dimensional evaluation matrix involving the impact of the initiative and the difficulty of implementation (Figure 3). The difficulty of implementation would feature the obvious constraints like cost, time, resources, and compatibility with an existing system.

Depending on the weightings placed on the main factors of impact and difficulty and on the sub-parameters such as cost and resources, this would enable quantitative evaluation and ranking of the initiatives if desired. Figure 3 presents an indicative scenario of initiatives prioritization where, by the combined evaluation initiative, A could be prioritized over initiatives B and C. We, however, recognize the uniqueness of context pertinent in various scenarios and leave the decision-makers to consider such evaluation tools at their discretion and modification.

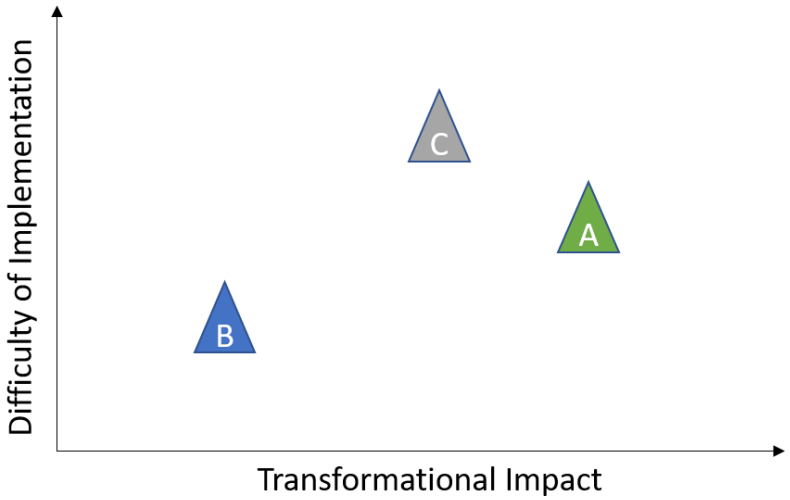

Figure 3: Prioritization Strategy

5. Conclusion

The COVID-19 pandemic has forced higher education into an experimental setup which was already a call of the time. With a full conviction that conventional education is here to stay for many more years and online education will be seen more as a complementary opportunity than a threat, we have attempted to provide a 360-degree view of the situation. We identify underlying issues, suggest solutions, and provide broad ideas leading to a sustainable, futuristic education system. We also take a pragmatic position about the digital divide and other limiting factors looming in the imminent transitions. The essence of this study, however, is to provide a holistic framework for the leaders, designers and policymakers of engineering education to integrate long-term strategies along with past and ongoing short-term management in the context of the pandemic-enforced situation. We believe the framework will initiate many important conversations that higher education needs to have.

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