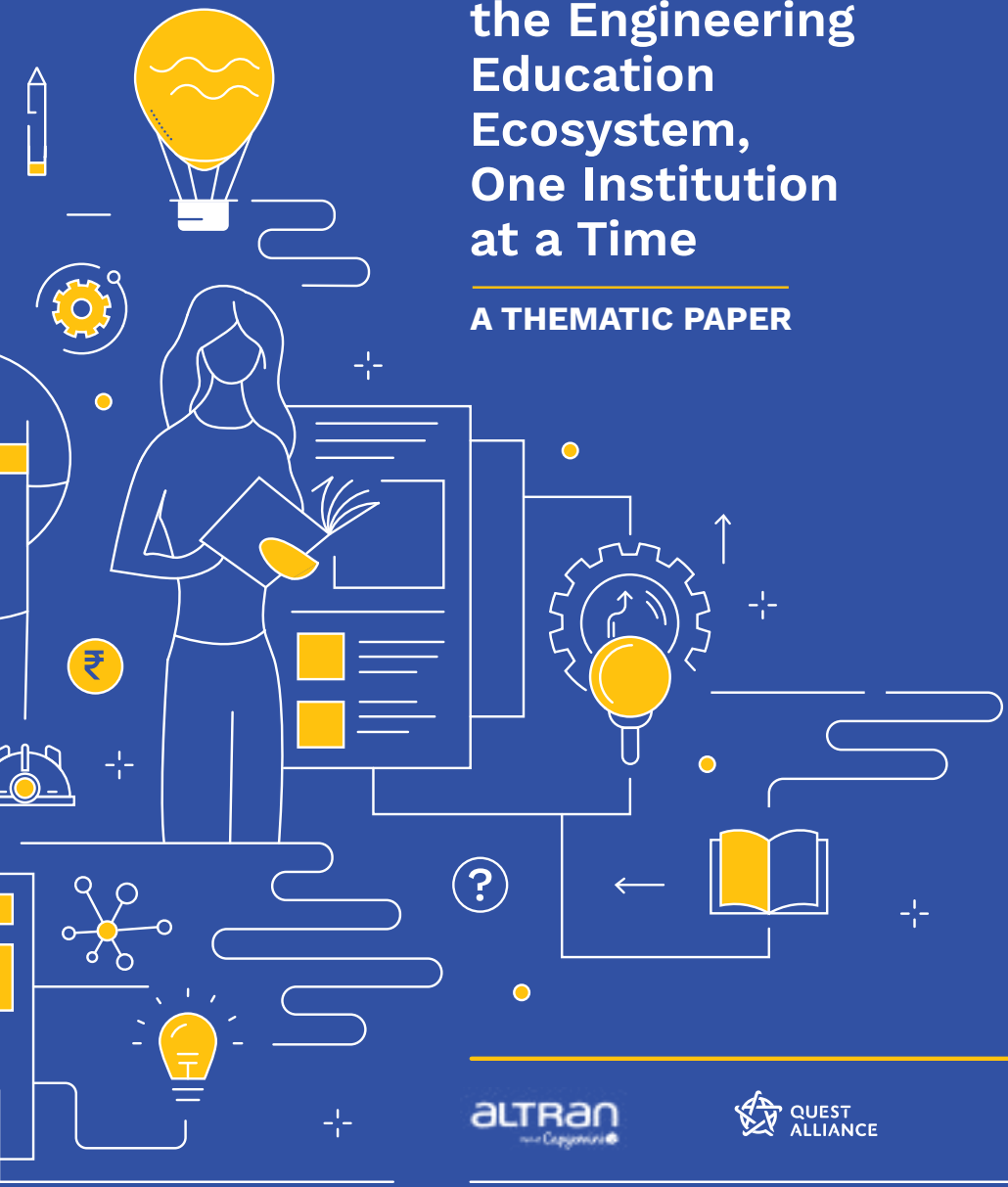
Transforming the Engineering Education Ecosystem, One Institution at a Time

A THEMATIC PAPER



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Executive Summary

The future of work and learning are radically changing the way we learn, work, live, and engage with our environment (Torii & O'Connell, 2017).

The complexities of problems society faces, such as climate emergency, poverty alleviation, are increasing exponentially (Reddy, 2019).

Tackling the climate emergency and meeting Sustainable Development Goals will require "tremendous innovation and ingenuity by engineers, working alongside other technical and non-technical disciplines" (UNESCO, 2010, 39).

These complexities could be addressed by Engineering interventions, through automation, technological enhancements, support, and cost-energy-saving innovations. However, Engineering as a discipline is floundering; an appreciable drop in student enrolment, a stark decline in the quality of graduates from the higher education institutions. In many engineering colleges, Educators does not focus on teaching, but uses this as a career pathway for lack of employment opportunities in this sector. Pedagogy that includes application-based learning, problem solving, or localized learning, is neglected. The lack of representation by marginalized communities, especially women, in science and engineering, is a glaring concern, which skews innovations, and workforce participation rates, thereby impeding the socio-economic development of our nation.

The changing nature of work and learning necessitates a drastic shift in pedagogy, learning environments, teacher preparation, Educators development programs, and facilities in engineering institutions.

In 2017, Aricent (now Altran), NASSCOM Foundation, and Quest Alliance collaborated to implement a blended learning program for educators in Tier II and Tier III Engineering Colleges, who participated in Altran's Arise on-campus program. The Arise ToT Master Coaches Program (Arise) was envisioned to bridge the demand-supply gap in the Engineering Ecosystem by improving the quality of engineering education. It harnesses experiential and digital learning to upskill educators, to advance the learning capacities of marginalized Engineering students.

In this paper, we present an array of concerns in the Engineering Ecosystem, both global and local trends. We also present solutions and recommendations to transform the Engineering Ecosystem. The three main stakeholders involved in this process are: students, Educators, and institutional leaders. Empowering these three stakeholders with 21st century skills, and self-direction, will in turn have its effect on industry, and policy makers.

Background

As our dependence on technology is increasing rapidly and advances in technology are proceeding at an ever-increasing pace, it is apparent that our dependence upon engineers will be even greater in the future (Kolmos, 2013).

The Indian Information Technology (IT) and Information Technology enabled Services (ITeS) sector is recognized as our flagship economy builder; every single rupee spent by IT-ITeS accounts for two rupees in the Indian economy. The Union Government of India has identified IT-ITeS as one of the 12 champion services sectors. It has also set up INR 5,000 crore funds to realize the potential of these champion services. There is an increasing demand for people trained in IT and ITeS skills even in other sectors like retail, automotive and BFSI, in response to the impact of digital transformation.

With a population of 1.3 billion and a median age of 28 years, India holds a golden opportunity on the demographic dividend in the Global Skills Landscape. Nearly 6-8 million youth are expected to enter the workforce in India each year for the next decade (Quest Alliance, 2017). According to the US National Science Foundation report, India accounts for one-fourth of the estimated 7.5 million Bachelor in Science and Engineering degrees awarded across the world. There are approximately 34,000 engineering colleges in India with over 1.5 million students graduating each year (Choudhary, 2017).

While the future continues to look bright for the Indian IT-ITeS industry and is anticipated to grow around 10% for several more years, it is critical to note that the talent requirements for new opportunities are different from that of the past (Perry, 2017). This response to the rising demand in the IT-ITeS sector along with the transition to a knowledge-based economy requires a new generation of educated and skilled manpower.

However, the national employability report for engineers published by Aspiring Minds indicate that more than 80% of engineering graduates are unemployable for any jobs (Aggarwal, Nithyanand, & Sharma, 2019).

Engineering Education: Concerns

Engineering and Innovation play a significant role in human, social, and economic development (UNESCO, 2010; Reddy, 2019).

The 19th century might commonly be known as the Great Age of Engineering, but it is in this one that Engineering gains true relevance. Engineering as a discipline promises to generate innovative solutions and support society's holistic development. However, the changing nature of our society, the labor market, and the rapid advancement in technology pose critical challenges to traditional engineering education in India. Some trends affecting the Engineering Ecosystem include:

A steady decline in student enrolment in engineering colleges (Reddy, 2019);

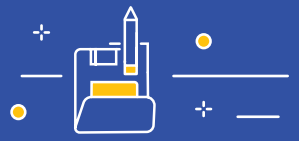
There is a widening skill mismatch of engineering graduates and the demands in the industry, which is also a global trend (Beanland & Hadgraft, 2013);

Significant difference in the access to resources, the quality of education, and placement opportunities between Tier I engineering colleges and Tier II and III colleges (Choudhary, 2017);

Despite the comparable female-male enrolment numbers in engineering colleges, the percentage of women participating and contributing to the field is low.

In addition to these trends, there are other concerns that affect the quality of education offered in engineering colleges:

The lack of qualified Educators;



Outdated pedagogy lacking in application of knowledge;

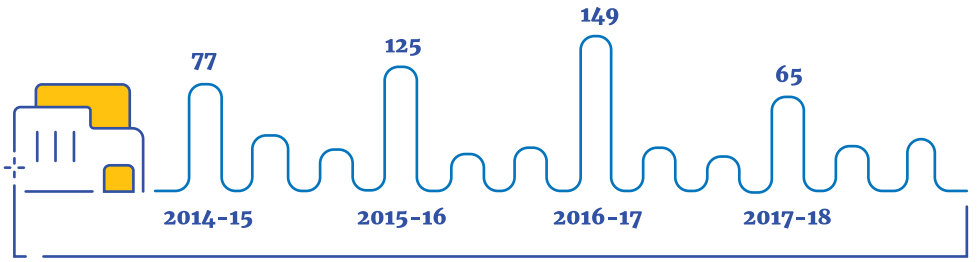
Absence of skills training for the workplace; and

Weak industry-academia linkages.

Enrolment in Engineering Colleges

Since 2013-14, there has been a steady decline in student enrolment in engineering colleges (Reddy, 2019).

There are 3,500 engineering colleges across India capable of enrolling over 16 lakh students. However, student enrolment has been less than 50% of available seats, which has led to the closure of some colleges. The number of institutes that have closed since 2014 is given below:



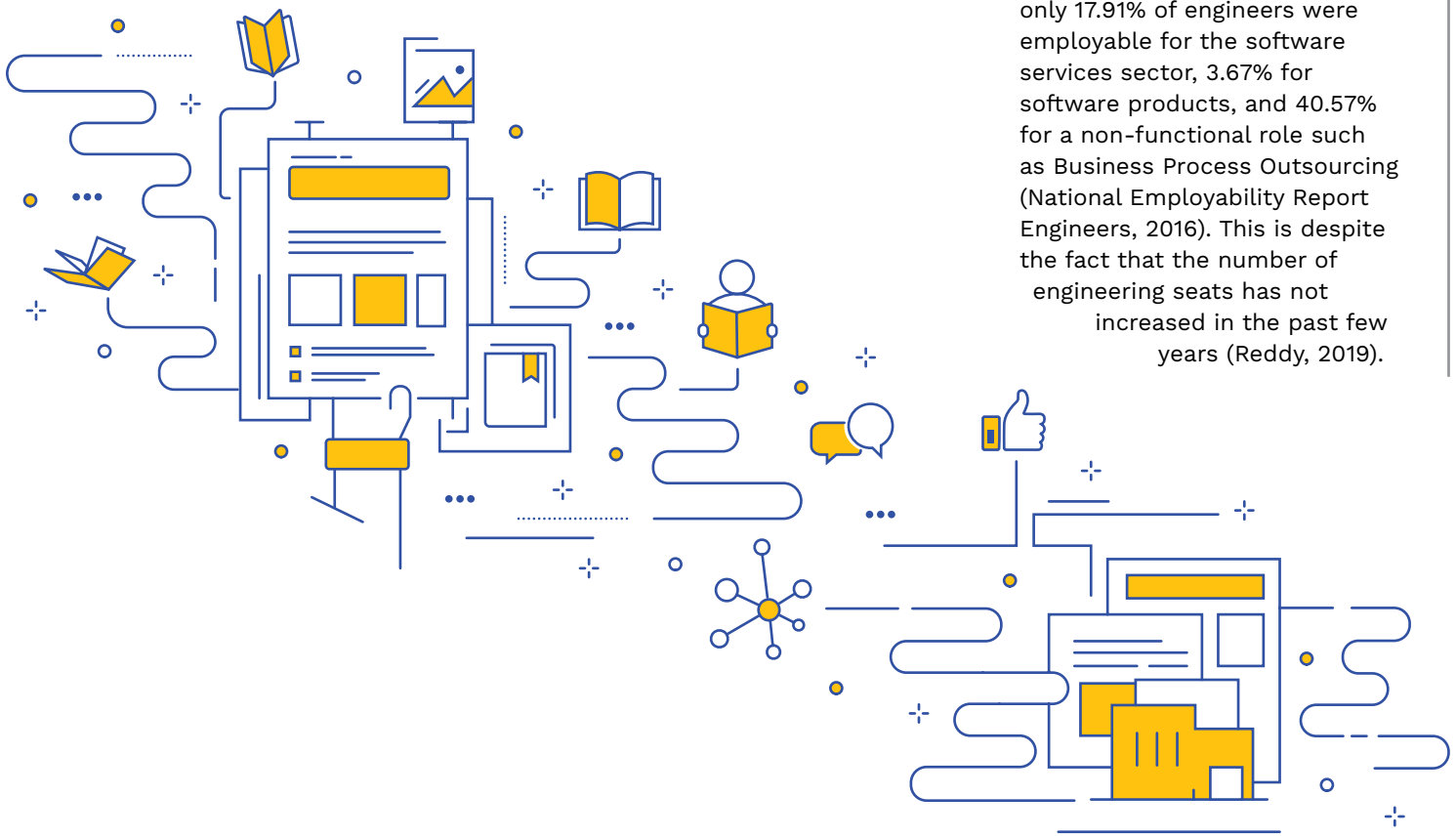
There are multiple reasons for this closure:

1. The quality of education in engineering institutes do not build life skills or help them solve real life problems (Sahoo, & Das, 2019).

2. Additionally, graduates from Tier II and III colleges especially, lack workplace skills such as communication, which negatively affects their placement. Low placement rates, combined with poor infrastructure, lack of hands-on application and learning-by-doing, also lead to poorer quality of these institutions.

3. The percentage of employable graduates is 2%, which negatively affects the placements offered by these institutions, which in turn has an effect on enrolment ratios.

Due to the changing nature of workplaces, and the lack of access to quality engineering education, the enrollment in engineering colleges has seen a steady decline. While Tier I colleges, which are centrally funded, enjoy the privilege of quality infrastructure, placement connections, quality Educators, and lab facilities, Tier II and III colleges, due to lack of funds, and access, are deprived of these, which in turn affects the quality of the education provided, and the probability of securing decent jobs.



Employability of Graduates

In India, there has been no significant improvement in employability in the last four years.

A recent report published by Aspiring Minds on the National Employability Report for engineers suggests that over 80% of engineers are unemployable in any sector (Aggarwal, Nithyanand, & Sharma, 2019).

Their earlier study indicated that only 17.91% of engineers were employable for the software services sector, 3.67% for software products, and 40.57% for a non-functional role such as Business Process Outsourcing (National Employability Report Engineers, 2016). This is despite the fact that the number of engineering seats has not increased in the past few years (Reddy, 2019).

The demand and supply gap is widening due to two reasons:

a) Unavailability of trained, qualified graduates to meet employers' needs, and

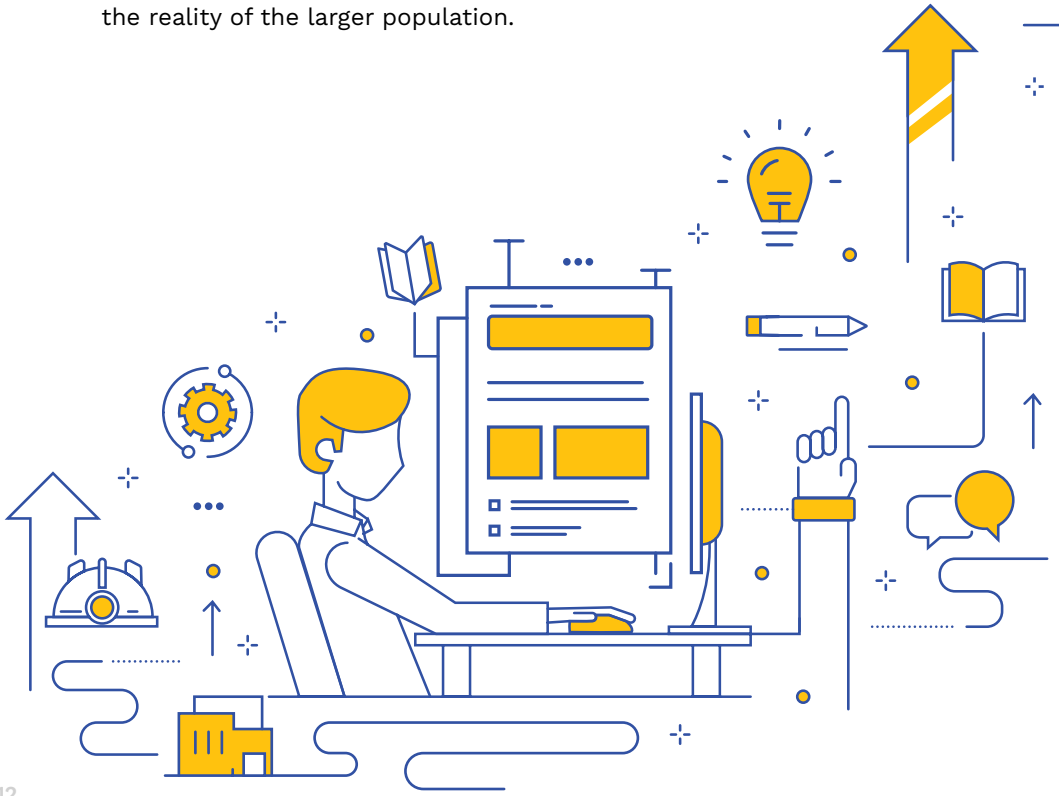
b) Downward enrolment trend in engineering colleges both at the graduate and postgraduate levels (Reddy, 2019). The disparity in gender inclusivity is also found in the field of engineering, despite the increasing trend in enrolment ratio.

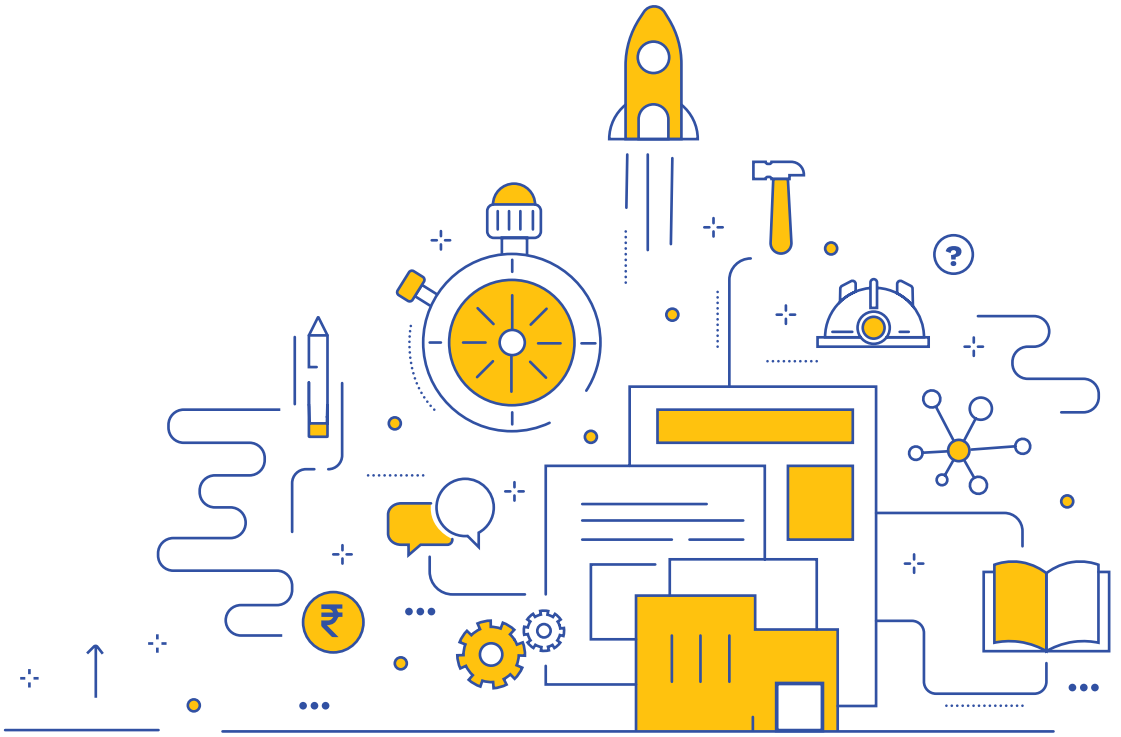
Some of the reasons for this trend include:

a. Deficient curriculum;
b. Inadequate development of the personal capabilities of graduates;
c. Inadequate development of graduates' personal capabilities;
d. Academic staff with little or no engineering experience (Beanland & Hadgraft, 2013).

Many young people struggle to find employment in the field they studied and trained for, indicating a mismatch between study decisions and employment opportunities. For instance, in 2016, only one-third (33.2%) of graduates were employed in the occupation they trained in (National Centre for Vocational Education Research, 2016). The implications of this could mean a) lack of employment opportunities in one's own discipline; b) lack of ability to secure employment that is aligned to one's education pathway; or c) a shift in traditional engineering roles in the current labor market.

There is also an increasing trend in open unemployment, where graduates choose not to take up an opportunity, because of misalignment between what they have studied and the skills required in the jobs that are available. Although, this is a privilege enjoyed only by a select few and not the reality of the larger population.





The Future of Work and Learning

Rapid advancements in technology and innovation are changing the face of the future especially in terms of the way we work, and what is considered as valuable learning. The future generations will navigate a vastly different world of work to that of their predecessors (Perry, 2017).

Technology is rapidly disrupting how we live and work – many tasks at the core of low and medium skill jobs are being automated (Quest Alliance, 2017). The skills that were much sought-after 10 years ago are on a steady decline, whereas skills pertaining to cognitive abilities are on the rise.

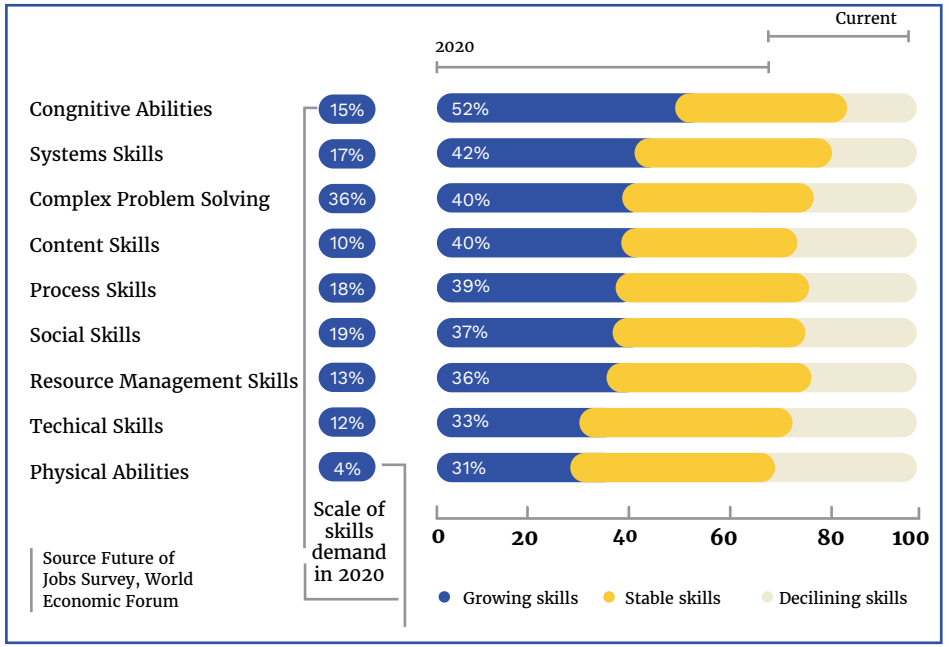
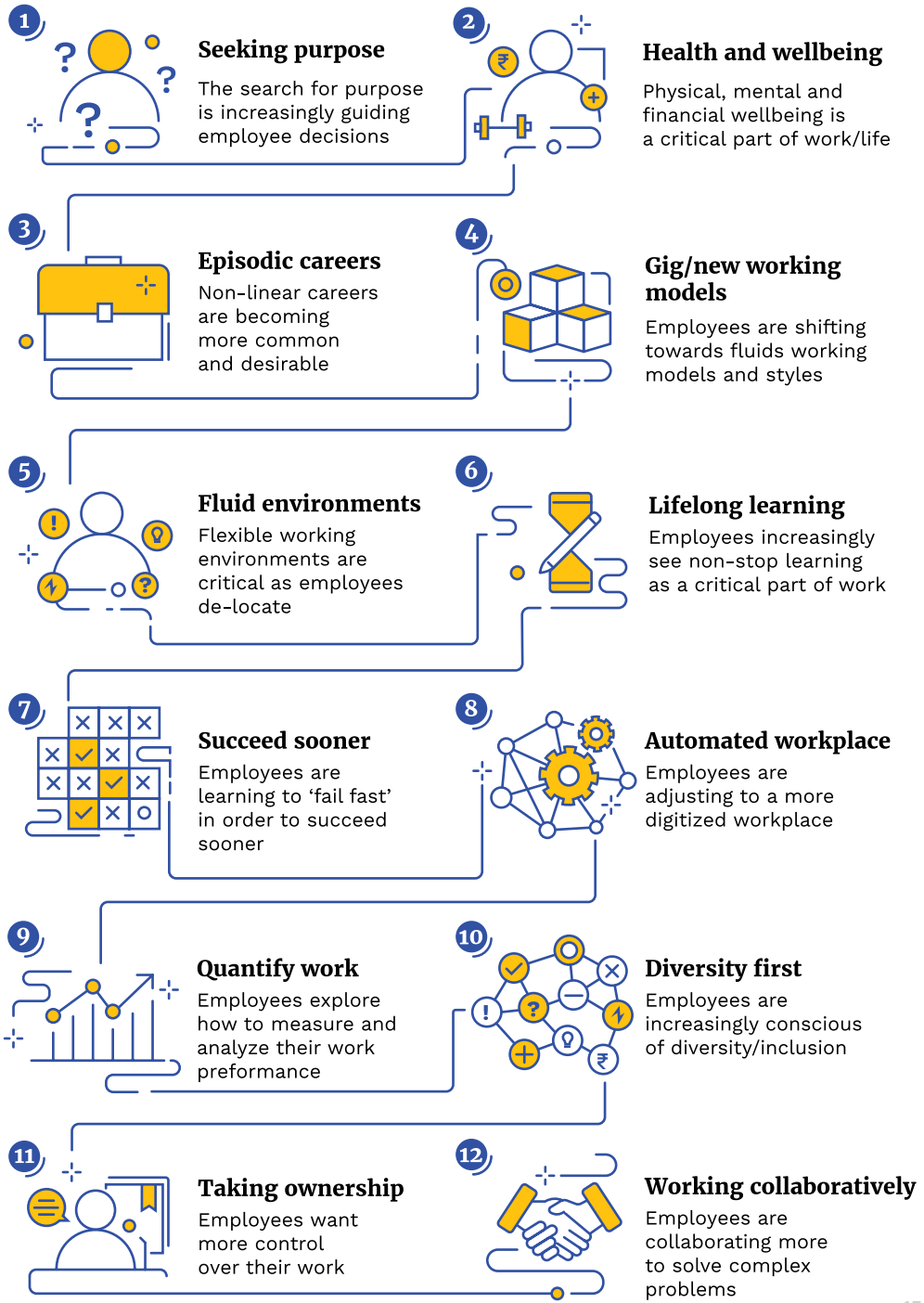


Figure 1 Skills needed in future jobs

As Figure 1 establishes, cognitive abilities will be in much demand in 2020 whereas physical abilities are on the decline. In the future, the need for creativity, problem solving sensitivity, and logical reasoning will be the core skill sets needed (Quest Alliance, 2017; Reddy, 2019). The readiness to learn fast, and fail fast, will accelerate one's path to success. The emerging gig and platform economies allow individuals to be fluid with employers, which also demands for continuous learning (Quest Alliance, 2017). Figure 2 offers an overview of the trends for success at the workplace for employees of the future.



Engineering graduates will need the following capabilities for the future (Kolmos, et. al, 2010):

- An ability to function on multi-disciplinary teams.
- An ability to identify and solve applied science problems.
- An understanding of professional and ethical responsibility.
- An ability to communicate effectively.
- The broad education necessary to understand the impact of solutions in a global and societal context.
- A recognition of the need for and an ability to engage in life-long learning.
- A knowledge of contemporary issues.
- An ability to use the techniques, skills, and modern scientific and technical tools necessary for professional practice. (Kolmos et. al, 2010, pp. 337)

The shift to these skills could be attributed to the innovations in automation, robotics, and machine science. Some research estimates that 40% of jobs are at high risk of being automated in the next 10 to 15 years (Durrant-Whyte, McCalman, O'Callaghan, Reid, & Steinberg, 2015). There is extensive evidence of accelerating demand for a variety of wholly new specialist roles related to understanding and leveraging these latest emerging technologies, such as AI and machine learning specialists, big data specialists, process automation experts, information security analysts, user experience and human-machine interaction designers, robotics engineers, and block chain specialists. Artificial Intelligence (AI) alone is poised to create 12 new job roles including solution architect, business analyst, data architect, data scientist, AI research scientist, language processing specialist, information security analyst, and DevOps engineer.

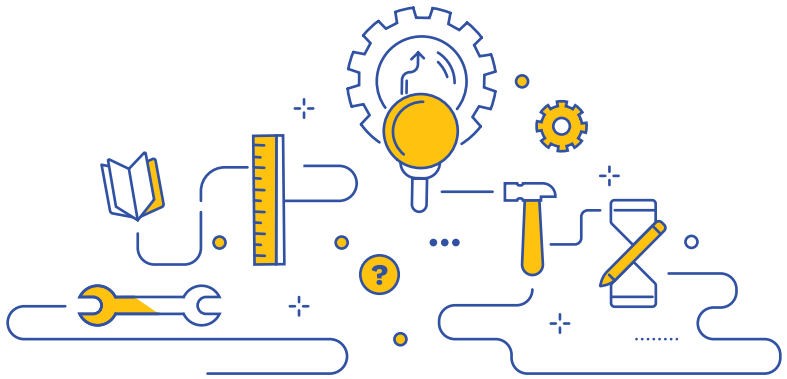
A large proportion of young people engage in unpaid work just to get a foot in the door, which makes it harder for those who cannot afford to work for free. A recent study by Oliver, McDonald, Stewart, and Hewitt (2016) found that 58% of 18-29 year olds participated in unpaid work experience. If the engineering education system does not nurture the skills called out in this research, then graduates will increasingly find it harder to find employment, and be successful at the workplace.

Teacher Education and Preparation

Generally, students' underprivileged conditions are quoted as the reason for not getting employed, but the actual crisis lies in the lack of quality teachers. The Educators is not properly trained to impart cognitive and technical skills to engineering graduates. The majority of the Educators in the country are engineers who choose teaching in engineering institutes only after they themselves misaligned or unfit for MNCs and other industries. Therefore most educated engineers join teaching by chance and not by choice, without any passion for teaching, but only to manage their livelihood.

> College Educators are forcibly assigned to handle those subjects beyond their scope, or they hardly have the better part of knowledge about the same (Personal communication, 2019).

Learning and teaching should go hand in hand, but a large part of the Educators is not interested in learning, and their understanding of the industry is outdated. Institutes' administrations are reluctant to appoint quality Educators to avoid the cost involved. The college administration especially in Tier II And III colleges seem to have failed to fulfil the needs of the students due to financial constraints.



Pedagogy and its Effects

Pedagogy plays a critical role in the learning process. The assumption that Engineering should focus solely on technical inputs restricts educators from integrating pedagogical innovations in their instruction.

> An absence of modeling professional skills such as problem solving, team work, understanding of organizational contexts, and communication, which are essential to be successful at the workplace (Brunhaver et al., 2018), creates a lag in graduates entering the world of work.

Universities and colleges do not lay emphasis on these aspects of learning for engineering students. Sometimes learning these skills is impeded due to lack of infrastructure and lack of emphasis on problem-based learning. The theoretical inputs do not compensate or prepare graduates to apply their technical knowledge at the workplace.

There is also a widespread concern about the lack of industry-academia partnerships, exposure visits, quality of Educators, and absence of facilities, especially in Tier II and III, where access to resources or networks is limited, for students to gain skills relevant to their workplaces.

Shortage of Industry-Academia Linkages

Industry-academia linkages play a vital role in ensuring that academic institutions are updated on recent industry developments, so that the curriculum is flexible and adaptable to help students prepare for the workplace. However, the past two decades has seen a progressive decline in these partnerships and have created silos in the way they function (Reddy, 2019).

> Apprenticeship has been a critical linkage between industry and academia. While the IT-ITeS industry currently employs four million professionals and should be enrolling at least 100,000 apprentices per annum, the industry has enrolled just about 23,158 apprentices (Reddy, 2019).

State of Industry-Academia Partnerships: AICTE-CII Survey 2018

Start-ups created through in-house incubation centers

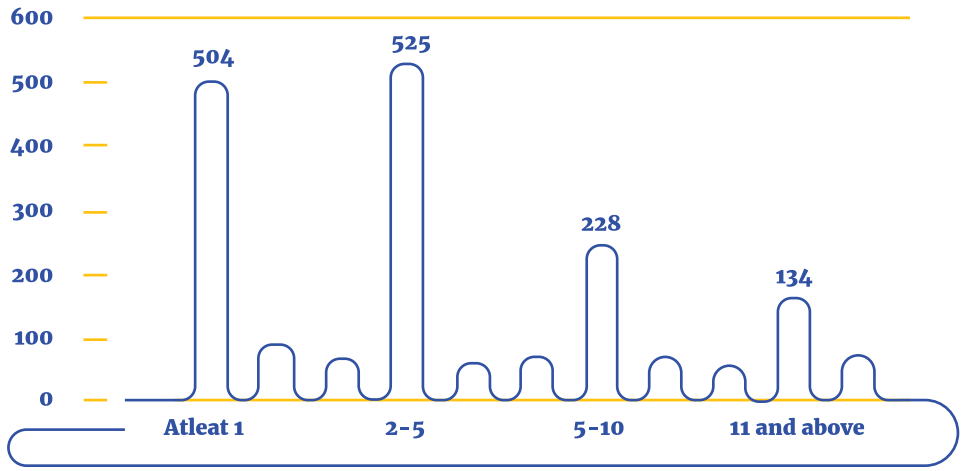


Figure 3 in-house incubation centers

To compensate for the lack of employment opportunities, particularly in Tier II and III cities, the need is felt to incubate new ideas, innovation, to encourage start-ups in these regions. Industry-academia partnerships could be leveraged to incubate these start-ups. However, there are very few industries that have incubated more than 10 start-ups in-house. Since Tier II and III institutions find it hard to engage with the industry due to lack of networking, resources, and capability, the translation of engineering graduates pursuing employment in the field of engineering is also insignificant. The need of the hour is for institution leaders and Educators to take initiative and make these connections to help graduates succeed at the workplace.

Women in Engineering

It is also critical to highlight the lack of equal gender representation and participation as one of the major concerns in the Engineering Ecosystem.

> The total female representation in higher education enrolment is 47.6% and a whopping 71.25% of all the students enrolled in engineering programs (B.E.) is male (AISHE, 2018).

In the changing work landscape, the already marginalized population, including women, are bound to experience further challenges both in the education and employment space (Quest Alliance, 2017). The report from the World Economic Forum highlights that only 14.3% of science researchers are women. The data shows that most of the students enrolled in doctoral programs in the engineering field are in mechanical, and computer science engineering, in that order, which is dominated by men, at 91%, and 59.84%, respectively (AISHE, 2018). Even in postgraduate programs, civil engineering has the highest enrolment, again dominated by men at 70% (AISHE, 2018). This further confirms the wide belief that Engineering is particularly favored by men, and within Engineering, certain fields such as mechanical and civil engineering is male-dominated. The lack of women representation in terminal degrees also gives rise to the question of the constraints women experience in science and engineering.

The implications of not having women represented in research and academia could have an impact on misrepresentation of the challenges that are faced by women (and other marginalized communities), which implies the lack of problem-solving that caters to the everyday realities of these populations as well. While the enrolment rates in Tier II and III colleges show almost equal representation, women enrolment in IIT is only 10% (Parikh, & Sukhatme, 2004). The implications will also result in widening the skills and pay gap between men and women, and lack of job opportunities for women in engineering.

Transforming the Engineering Ecosystem

In order to transform the Engineering Ecosystem, a three-pronged approach of working with the industry, institution leaders and Educators, and students, is recommended to help them navigate the challenges of the future of work and learning, as confident professionals. Here, we would like to highlight the existing partnership between Arise and Quest Alliance, to transform the Engineering Ecosystem, through a systemic approach.

The Arise Program

The Arise program is executed in partnership with Altran and Quest Alliance. The focus of this program is to

- Create knowledge and resource pools to improve pedagogical approaches for quality improvement in engineering education.
- Build institutional capacity as self-learning hubs for dialogue, best practice-sharing, and stories of change, to create more responsive systems.
- Build a favorable socio-cultural shift in institutions that support systemic reform, thereby removing alienation in the engineering education ecosystem.
- Build enabling 21st century institutional culture through capacity-building programs for principals, directors, and management.
- Foster a growth mind-set in leadership, supporting them to become change agents who adapt their institutions in the context of the future of learning and work, to create enabling environments for their educators and learners, enhancing their agency and choices.

This program believes in the training of trainers as the first step towards transforming teacher education in the Engineering Ecosystem, thereby enhancing students' academic engagement and performance, in order to meet the demand around the future of work in the engineering sector.

The required human and machine collaboration means young people in engineering classrooms need to be taught differently. The shift in the Educators's thinking and a campus culture can resolve the anxieties around "engineering students not being employable". How learning happens in these classrooms needs to remove the barriers between theory and the lab, equipping young people for real-world application. If technology is rapidly changing, and human and machine interaction is evolving, those who build, design and use the power of engineering need to be included in the shift and be prepared for the world of work.

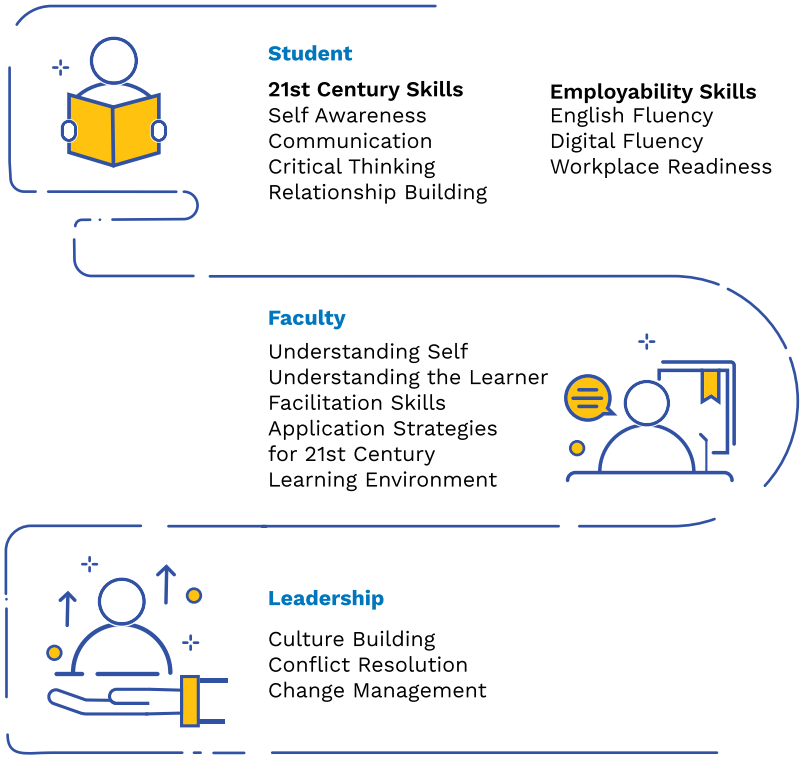


Figure 4 The three-pronged approach of the Arise program run by Quest Alliance

As Figure 4 indicates, the emphasis of the program lies in nurturing self-learning ecosystems. It allows for leaders, Educators, and students, to exercise their agency, and make choices that will affect the way they engage with learning, decision-making, and eventually, success at the workplace. These self-learning ecosystems are anchored on 21st century skills such as critical thinking, collaboration, creativity, and communication, which we have established are indispensable in the rapidly changing world of work.

The program was established based on existing literature, which recommends changing the narrative by focusing on some critical areas. Before delving into how the transformation is possible, it is also important to acknowledge that this transformation is not only imminent but opportune as well. Figure 5 below shows that Asia along with South America and Australia are considered as emerging leaders in the space of innovation engineering (UNESCO, 2010). We are at the crossroads of leveraging this opportunity, while battling the challenges that prevent Tier II and III cities from nurturing high-quality engineering graduates, ready for the 21st century workplace.

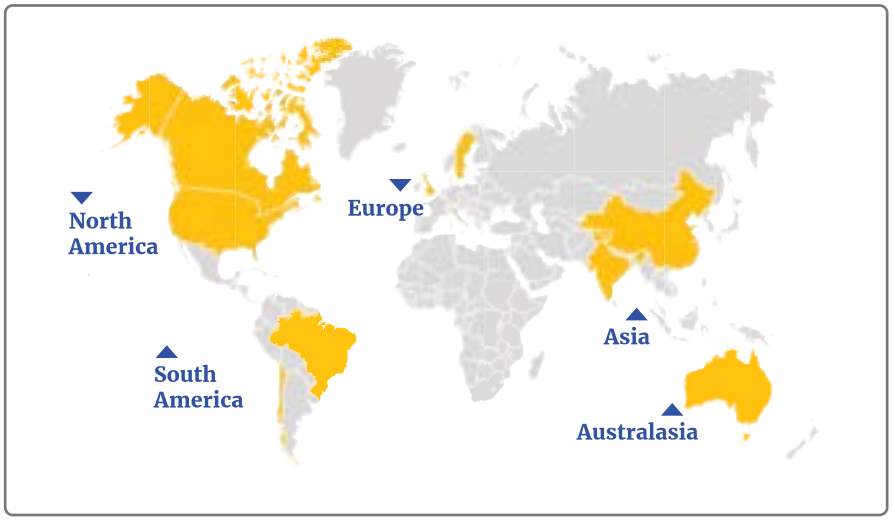


Figure 5 emerging leaders in engineering

Professional Development of Engineering Educators

The first step towards transforming the Engineering Ecosystem is to invest in Educators development. There needs to be a significant focus on non-technical, facilitation skills, to create a 21st century learning environment. The training of trainers offered by Arise is a step towards helping Educators develop self-awareness, learning the art of creating self-directed learning environments, and supporting students to choose their own learning pathways.

In addition to helping Educators learn facilitation skills, their competencies need to be developed in new-age technologies and research through rigorous Educators development programs. AICTE is likely to introduce six-month teacher training for Educators employed in engineering colleges, in order to help them engage in continuous, life-long learning, and be up-to-date on trends in the ecosystem.

Rethinking Learning Environments and Pedagogy to Enhance Placements

Today's job market in the engineering ecosystem requires 30% of technical skills, and 70% of soft or professional skills to succeed (Reddy, 2019).

Young people will need 21st century skills to succeed in technology-rich, globalized, competitive job markets. We need to adapt our approaches to learning so that young people are equipped with the capabilities that will enable them to thrive in these complex and rapidly-changing education and employment settings.

While there are small changes taking place in offering communication classes, and collaborative exercises, there is a need to rethink engineering education, which allows for experiential learning of these 21st century skills. There is a need for "a more fundamental change in engineering education towards more student-centred learning, complex problem analysis and complex problem solving, interdisciplinary knowledge and competences, and global and intercultural understanding at a curriculum level" (Kolmos, 2013).

Including analytical thinking to understand the impact of various teaching methods and identify the best methods of executing coursework will help Educators to innovate their pedagogy and place students at the center of the learning process. There is a need for a close integration of apprenticeship with pedagogy in order to help students apply their theoretical learning into local, and real-life problems (Reddy, 2019).

Students' Cognitive Engagement

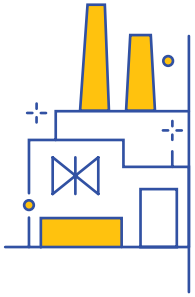
Engineering education needs to effectively cater to the needs of millennials and centennials to address lower attention spans, and the need for flexibility in learning (Reddy, 2019).

One of the biggest concerns in the Engineering Ecosystem is the lack of student engagement, manifested in the form of declining enrolments in engineering colleges. This calls for a pertinent shift towards student-centricity. There is the need to rethink pedagogy as a combination of on-campus and off-campus learning, which is personalized, flexible, and experiential.

While academic performance has been the only indicator of success for students, there is also a need to rethink what success is for a 21st century graduate. The engineers who graduate do not work in silos and have to interact with society and interdisciplinary teams at large. Since engineering innovation caters to societies, these collaborations are a given. However, the current program design does not allow for a wider engagement with disciplines outside of engineering. Fisher and Mahajan (2003) point to the need for this interdisciplinary learning in the Engineering Ecosystem: "the increasing complexity of societal issues, environmental considerations, and technological progress means that engineers are being asked to make decisions that not only require technical expertise but also a keen understanding of broad, socio-humanistic contexts and considerations". Ethics, decision-making, project management, become essential courses in the design of engineering programs. If the integration will take time, there is also a need for opportunities that are societally relevant, and involving multidisciplinary streams where students make choices and experience collaborations outside the classroom (Reddy, 2019).

Strengthening Industry-Academia Collaborations

The only way to keep abreast of the changes in the world of work is to create strong partnerships between industry and academia. These partnerships could manifest in the form of



Industry actively participating in academic boards

Strong research and development wings in academic institutions, in collaboration with industry partners.

Academic institutions need to continuously monitor future skills requirements and make suitable changes to content and pedagogy so that graduating students have the right capabilities for the job-in-demand. This could be achieved through a periodic industry feedback on technology upgrades and their impact on jobs, roles, to the institutions (Perry, 2017; Reddy, 2019).

There is also a need to review partnerships as above and beyond placements. Regular interactions between Educators and industry could be scheduled to gain inputs on curriculum, proactively explore potential joint research projects, and create more start-ups that can complement and supplement industry needs (UNESCO, 2010).

Conclusion

Transformation begins with redefining, rethinking, and reimagining the current realities.

1. Place a continuous thrust not only on working at the frontier but creating new frontiers. This means to lead and not just follow. Let us redefine what student success means in the Engineering Ecosystem.

   Can we prepare engineers who are self-reliant and adept at continuous learning, to develop interdisciplinary, contextually relevant, engineering solutions for their people?

2. Focus on strengthening teaching-learning environments.

   Can we move beyond semester-based evaluations to creating 21st century learning environments that allow students to use their agency, access relevant tools and resources, and lead their learning journeys with guidance from their Educators? Can we support our Educators with continuous learning pathways, and nurture their capacity to guide their students effectively?

3. Expand students' understanding of complex technological processes and situate them in the context of social, environmental, economic, and global concerns (Reddy, 2019).

   Can we align our engineering graduates towards a holistic, perspective-building of their local contexts, in order to adapt global solutions to engineering problems?

4. Alter the curriculum in institutions to include lifelong learning attitude in Educators and students, include more Liberal Arts exposure, and life skills (Perry, 2017).

   Can we ensure our students experience a wider understanding of their realities, and gain tools that will help them self-navigate in times of unprecedented change?

5. Build industry-academic partnerships to be attuned to the trends of the future of work.

   Can we provide tools and resources to institution leaders to maintain relationships, and engage in mutually beneficial collaborations?

6. Invest in building systems that increase the enrolment and participation of women, and other marginalized communities, in the field of engineering.

   Can we create strategies that increase women representation in Tier I colleges, nurture women in engineering to showcase role models who could inspire more girls to choose science and engineering, to stay and contribute to the field, and build careers for themselves?

Responses to these questions will frame the strategies that lie at the heart of transforming the Engineering Ecosystem. While the trends observed in this report are universal, the shifting work opportunities in India gives us an edge to prepare engineering graduates to face the future of work and learning. It is a collaborative effort. A handful of governing bodies will not be able to implement this on their own. Partnerships between industry, academia, policy makers, and civil society organizations such as Quest Alliance, could help build pathways for this transformation to come to fruition.

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