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Inclusivity in Engineering Curriculum in the Age of Industry 4.0: The Role of Internet of Things

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Abstract

In the absence of digital technology, the cost to operate an inclusive education system is prohibitive. Prior to the digital revolution of industry 4.0, the evolution of the education system resulted in limited access and limited accommodation for underprivileged populations. In this paper we provide case studies that illustrate how students that are economically disadvantaged and students with atypical learning styles have suffered the most. We then describe how the application of digital technology, in particular we explore the Internet of Things (IoT), is making inclusion possible and affordable.

The case studies will show that the evolution of the education system, driven by economic efficiency, has resulted in two types of exclusion. Without technology, the "affordable" education system has been delivering programs designed for a limited range of learning styles, and only to those students and societies with the economic means and physical infrastructure to afford it. Instead of education operating as a vehicle to close the economic gap between the *haves* and *have-nots,* a lack of global access has widened the gap. In addition, when education programs are delivered as if all students have identical learning styles and needs, the students with unique learning styles are put at a disadvantage. Fortunately, with the proliferation of digital technology, access has expanded to the masses and education programs can be tailored to the needs of the learners.

Despite economic and social disadvantages, non-traditional learners can be given equal access through IoT enabled technologies. We do not accept the premise that the way to deliver affordable education is to only accommodate an exclusive population of students

while the less conventional students are forgotten and left behind. Instead, we show how IoT can be used to bring the outlier students into the system. IoT can also be used to provide substantial educational assistance. IoT creates opportunities for vicarious and virtual inclusion. IoT is the tool, and now is the time to build an education system for all students, not just those that fit academia's cost-efficient model of mass education. The paper includes cases where IoT is being successfully used to democratize education.

Keywords: Education 4.0, Industry 4.0, IoT, Remote learning, Inclusive education.

1. Introduction: Inclusive and Exclusive Education

Perhaps the term "inclusive education"[1] is best understood as one that removes barriers to entry and accommodates a wide range of learners. Legacy education systems were based on economic efficiency. Whether intentional or not, these systems exclude economically disadvantaged students. Furthermore, programs designed to suit the majority of students can exclude those that don't fit the standard. It can be argued that the evolution of the education system, driven by economic viability, was unavoidable. But that does not mean the education system should continue as-is because "that's the way it's always been done." The absurdity of that argument might best be illustrated by a metaphor. If we think about the education system like a highway and the learners like drivers in vehicles, we might say that prior to the introduction of technology, the education highway had very few on-ramps. If they could reach an on-ramp and enter the highway, the driver would quickly discover that only one type of vehicle and only one speed was allowed. If their vehicle was slightly smaller or larger, or slower or faster, it would be quickly run off the road. In this metaphor, it is clear to see that a highway designed this way would be unacceptable, yet in traditional education systems this design has been acceptable. Specifically, some of the known roadblocks to inclusive education are:

a. Lack of Financial Resources: Poverty is probably the chief reason for exclusion. Poor children and poor youth not only lack the resources to afford education, they also have to get busy seeking work for sustenance of self and family. Without education they remain unable to move up the economic ladder and the cycle of exclusion continues from one generation to another.

b. Limited Access to Technology: Historically, first world countries have always enjoyed the technological advantage. New technology, whether it is the smartphone or internet access, has spread in first world countries much faster. With the world of education rapidly moving into a digital realm this is creating a new source of exclusivity.

c. Limited Social Status: Status in society whether it is due to the gap between the *haves* and *have-nots* or due to race, ethnicity, etc., all lead to large swaths of population being excluded.

d. Limited Physical Ability: Disability of any sort could be a cause for effective exclusion. People who are wheelchair bound, have prosthetics, of poor sight or hearing, etc. face significant barriers. Many of these barriers are starting to break down in the first world but that is hardly the case in the developing world. Conditions such as Autism, while not quite a physical ailment, provides its own challenges as well.

e. Personality and Learning Style: Some students are good at learning by reading from a textbook or by passively listening to a lecture. Others feel stifled and bored in the classroom where the entire learning mode is passive listening. They learn by doing or through tactile activities. An overwhelming majority of our learning systems are set up to be used as a passive learning resource. This effectively excludes students who are not good at working in that mode.

Inclusive systems seek to remove barriers and provide the means for educating ALL students with high quality instruction, interventions, and support such that all students have the opportunity to be successful. Inclusive schools have a collaborative and respectful culture where all students are presumed to be competent. They encourage and develop positive social relationships between peers and recognize all students as fully participating members of the school community, regardless of their financial standing, social status or physical ability.

The National Longitudinal Transition Study-2 (NLTS2) [2] reveals that the percentage of courses students with learning disabilities take in general education classrooms is related to both their academic performance and their social adjustment at school. However, having access to the general education curriculum means that students' educational programs are based on the high expectations that each student will contribute to society and that includes students with disabilities if they receive needed accommodations.

In individual studies [3],[4], thirty years of research show that when students with disabilities are included, all students learn and achieve more. Inclusion leads to lower rates of suspension and drop out, and to higher rates of employment. The outcomes include performance in community living and work contexts, interactions with schoolmates and co-workers, independent participation in naturally-occurring activities, and quality and size of a natural support network. These findings are true for individuals with learning disabilities as well as those who require significant and life-long accommodations. Beyond other fellow students, it is also important to the society as a whole to include every student in the education process. Without that the society will lose out on many talents who would not be able to thrive and contribute to the betterment of the society. The United States Constitution’s 14th Amendment says [4]: No State shall make or enforce any law which shall abridge the privileges or immunities of citizens of the United States; nor shall any State deprive any person of life, liberty, or property, without due process of law; nor deny to any person within its jurisdiction the equal protection of the laws. Inclusion is essentially codified in the constitution.

Sometimes, inclusive education is considered to be a program designed for people with physical or cognitive disabilities only. In this paper, we are broadening the definition of inclusion to mean non-exclusive, open to all people. This definition would include people that lack financial means and those that have limited opportunities to change their social standing, or limited access to digital resources. These individuals exist in the first world countries as well as the rest of the world. IoT holds the promise to provide inclusive education for all! [5][6]

2. Scale of the Problem of Exclusivity: Two Case Studies

2.1 Case Study on Sub-Saharan Africa

Before discussing the future promise of IoT, we need to have a basic understanding of the state of inclusive education today. How inclusive is it? Do all people have opportunities? Which population is being left behind? Where are the biggest challenges? What are the opportunities for improvement? In this section we consider two case studies which highlight two scenarios of exclusion. The first case study uses publicly-available data on worldwide access to education. This is meant to provide a snapshot of the scale of the problem of exclusivity.

To understand the education landscape, one needs to look at the world population data and explore where the highest needs are. Data on median age distribution across the world in different countries show a very interesting trend. The top ten countries with the highest percent of population that are of age 15 or younger are in sub-Saharan Africa (Table I shows the list of only the top ten) [7]. Incidentally, USA is #158 on this list with about 18.5 percent, India and China being the two most populous country are #91 with 26.1% and #171 with 17.3%, respectively [7]. It goes without saying that education access needs are paramount in the countries with large youth populations and these are the same places where access to education and the internet is the most challenged.

Table 1: The top ten countries with the highest percent of population that are of age 15 or younger [7].

Rank	Country	% of population	Time Stamp
1	Niger	50.6	2020 est.
2	Uganda	48.2	2020 est.
3	Angola	47.8	2020 est.
4	Mali	47.7	2020 est.
5	Chad	47.4	2020 est.
6	Congo (Democratic Republic)	46.4	2020 est.
7	Malawi	45.9	2020 est.

8	Zambia	45.7	2020 est.
9	Mozambique	45.6	2020 est.
10	Benin	45.6	2020 est.

Figure 1 lists the countries with the lowest percentage of internet penetration in the world [8]. These two statistics together paint a dire picture. Barring North Korea, many of the countries with lowest internet penetration are also the sub-Saharan countries that have the highest percentage of youth population. As opposed to this, countries such as China, India and the USA have the highest penetration of internet [9].

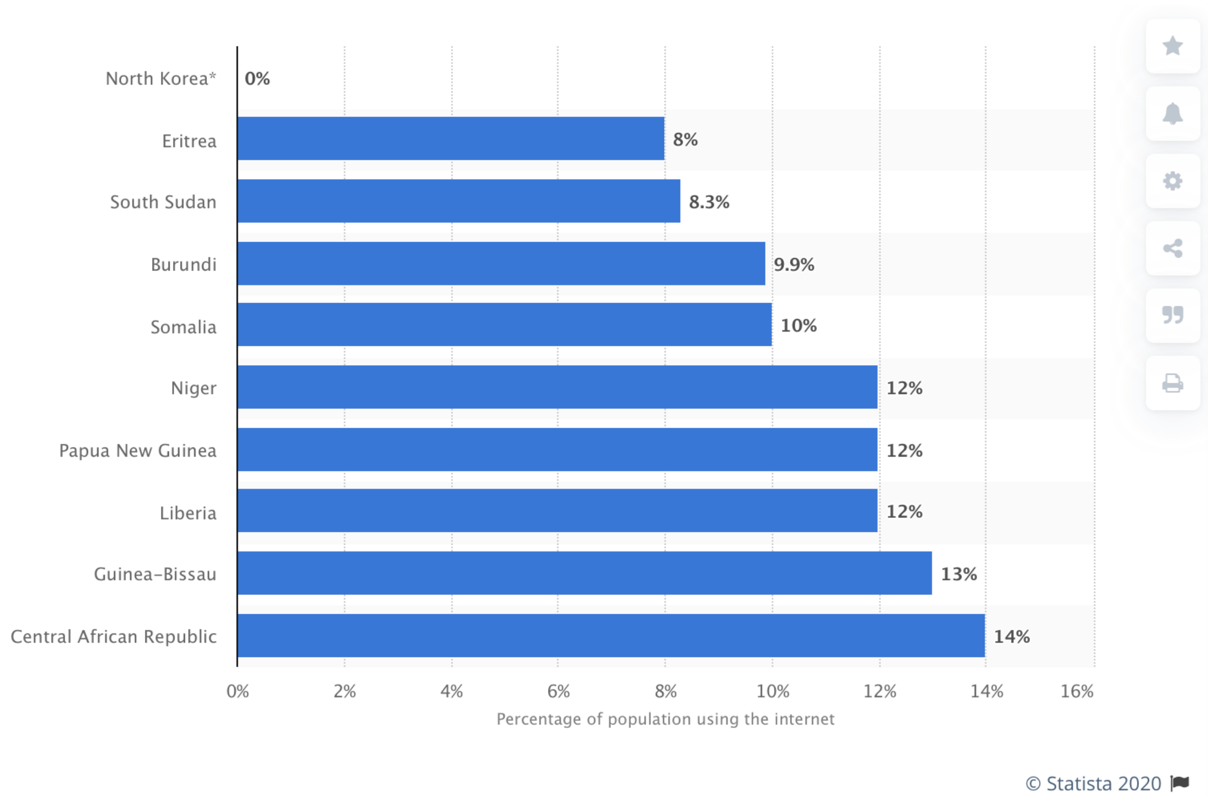

Figure 1: Countries with Lowest penetration of Internet [10].

Now consider data on pupil-teacher ratio. Education opportunities all across the world have been expanding over the last few decades. And in many parts of the world this expansion of education has led to reductions in pupil-teacher ratios. In Norway and Sweden there are on average 9 primary-school students per teacher. However, in the Central African Republic, there are about 80 [11]. In sub-Saharan Africa, the average number of pupils per teacher in primary education has increased with the expansion of education (Figure 2).

This trifecta of higher youth population, lower internet connectivity, and higher pupil to teacher ratio makes sub-Saharan Africa a unique geographic region where access to education through technology such as IoT is both a paramount need and a unique opportunity. Efforts to include this population in a meaningful way in the global educational access is therefore a critical challenge.

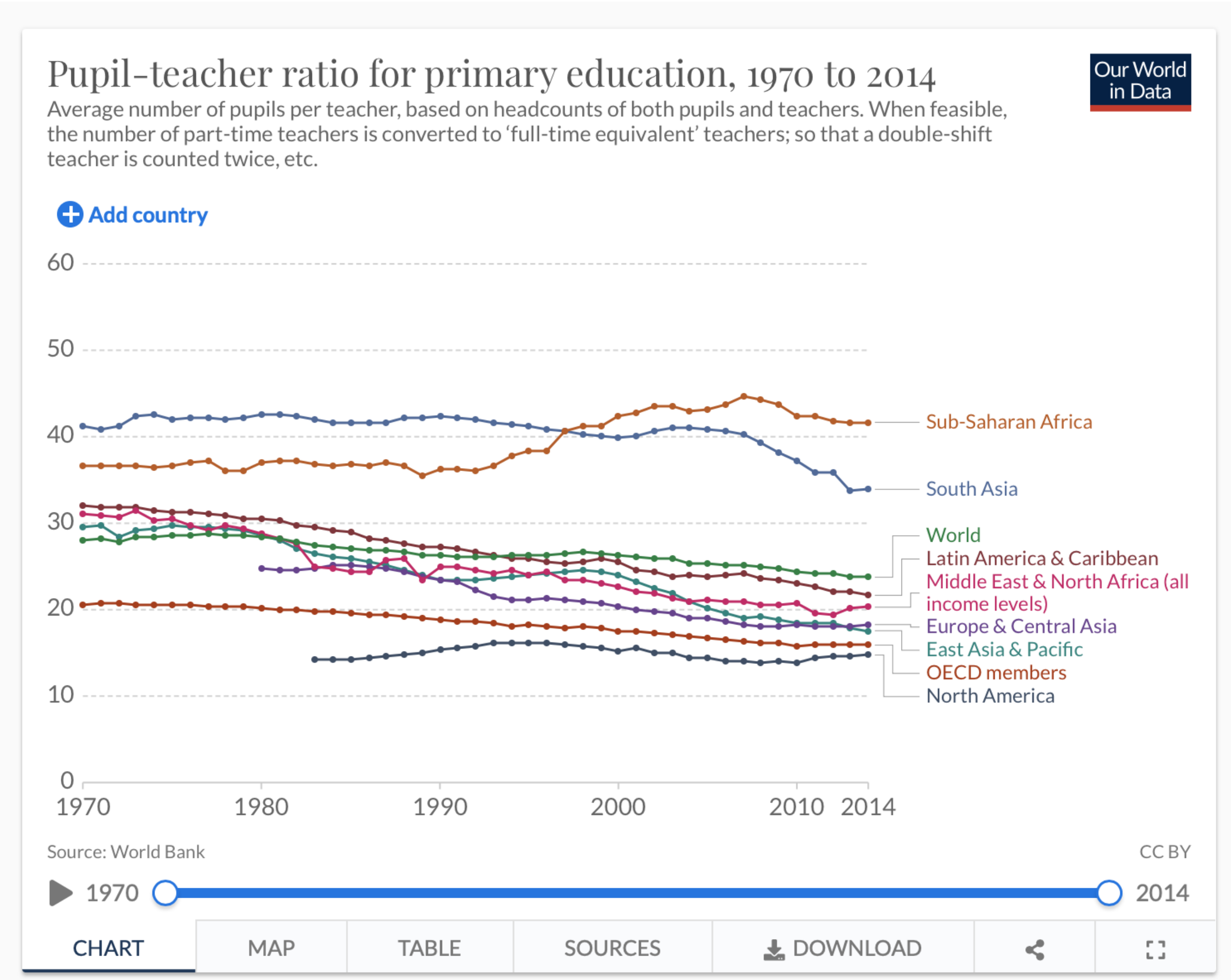

Figure 2: Pupil-teacher ratio for primary education in world regions [11].

Across the world there were 60 million children of primary school age out-of-school in 2014 [12]. Data shows that about 57% of these children are in sub-Saharan Africa. The chart in Figure 3 [12] shows the world-wide distribution of primary-school-age children who are out of school. Although progress is being made, the sheer number of children who are not in school remains unacceptably high.

While the large number of children out of the classroom is a terrible situation indeed, a recent UNESCO report [13] from 2017 shows that more than 85% of children in sub-Saharan Africa who are in school are not making sufficient progress to become proficient in reading, writing and mathematics. New data from UNESCO Institute of Statistics shows that 88% of all children and adolescents will not be able to read proficiently by the time they are of age to have completed primary and lower secondary education (see

Figure 4). This means 137 million adolescents are in school, but not learning the minimum.

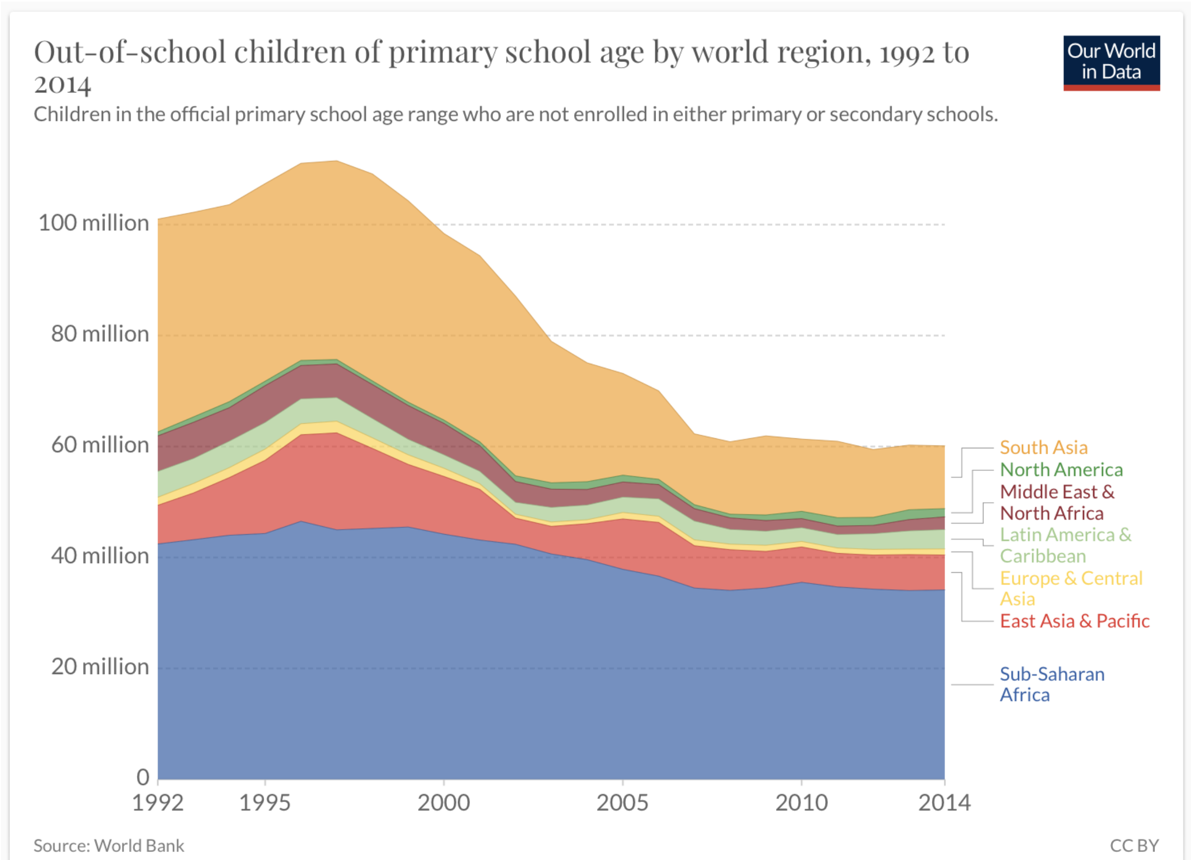

Figure 3: Primary school age children who are out of school [12].

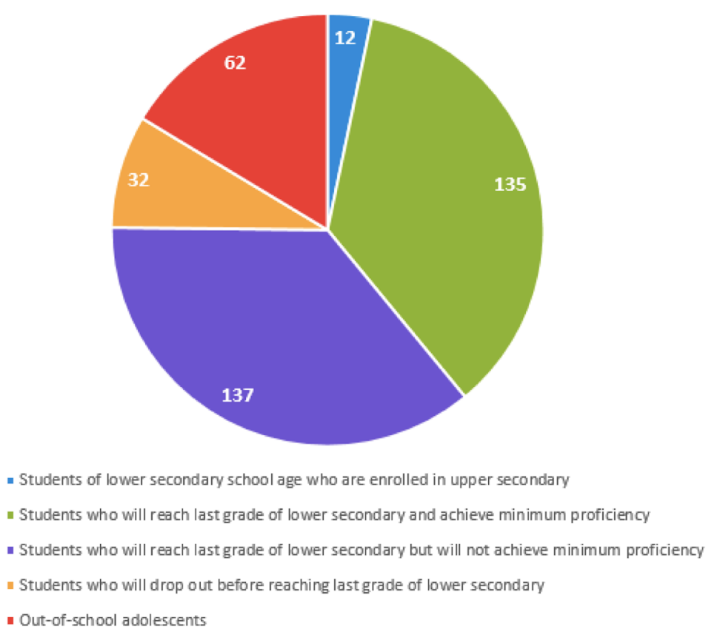

Figure 4: Students in primary and lower secondary schools in millions [13].

The situation in sub-Saharan Africa seems particularly dire; there are other low-income countries which are in alarming situations as well. Nighty-one percent of primary school-age children in low-income countries will not achieve minimum proficiency levels in reading and the rate is 87% in math, compared to 5% and 8% respectively in high-income countries. Work is going on in Africa to improve this situation through the use of IoT and other related technology [14]. There is still enormous work to be done in Africa's education system to ensure that all countries uniformly meet the 2030 United Nations Sustainable Development Goal, to "*Ensure inclusive and quality education for all and promote lifelong learning*."

As is clear from this data the world-wide waste of human capital is staggering. Getting children in the classroom is only half the battle. What happens or does not happen when the children are in their learning environment is a matter of concern too. Data from UNESCO Institute for Statistics [13], [15] indicates that the whole problem can be divided into three parts:
(a) Lack of access for children who are not in school or have no chance of getting in school,
(b) Failure to retain every child in school and keeping them on track, and
(c) the issue of quality of education and what is actually happening in the classroom.

Improving these situations will require commitment and resources but also a new approach to improving the quality of education. This is where IoT can play a very distinct role. Internet of Things in conjunction with innovations in pedagogy can address all the three issues of access, retention and quality. Proven techniques and emerging applications of IoT can be applied to this large swath of populations to help them improve quality and bring inclusivity to education.

2.2 Case Study on Student Learning Styles

The purpose of this case study is to employ data-driven methods and techniques to gain insights into student learning styles that can be used to modify, strengthen, and improve pedagogical approaches to undergraduate engineering education.

To collect data, our academic team partnered with TTI Success Insights, a 30-year-old Arizona-based firm that serves clients in 90 countries and 40 languages. The firm is the global leader in providing research-based validated compliant assessment and coaching tools that enable organizations to meet their talent management needs. Their client base includes Fortune 500 companies, government agencies and educational institutions around the world.

<u>TTI TriMetrix® DNA Assessment Suite</u>

For data collection, the TTI TriMetrix® DNA assessment suite was used (Figure 5). The TTI TriMetrix® DNA assessment suite is comprised of three self-reporting assessment instruments that are administered via an online portal. Each of the three self-reporting assessment instruments are independently validated.

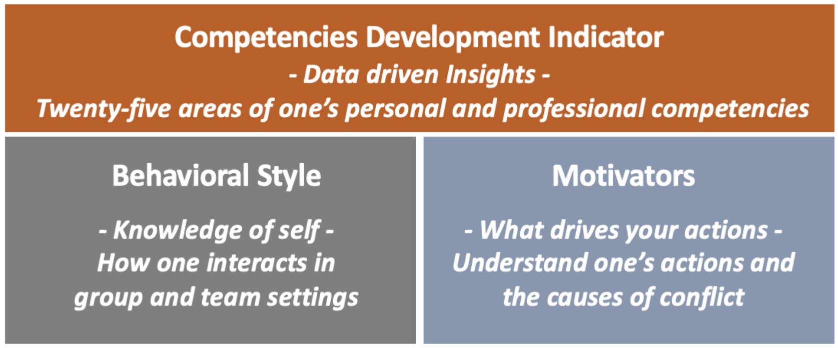

Figure 5 - TTI TriMetrix® DNA Assessment - Competencies, Behavioral Styles and Motivators

The authors have administered over 10 thousand TTI TriMetrix® DNA assessments relating to engineering education and professional development. There have been a series of peer reviewed research papers published using the TTI TriMetrix® DNA assessment suite that investigate engineering education and professional development.

<u>Sample and Research Methods</u>

Drawing from a data sample of 4,965 undergraduate students, and 313 entrepreneurially minded engineers, the work of Pistrui, et al. employed the TTI TriMetrix® DNA in a combination of descriptive and multivariate methods and techniques that quantified specific behavioral attributes and professional competencies found in entrepreneurially minded engineers [16]. The doctoral dissertation research of Dietrich (2012) was able to quantitatively distinguish between engineers and entrepreneurially minded engineers in both behavior and mastery of professional skills in the workplace [17]. Research by Pistrui et al. used the TTI TriMetrix® DNA assessment suite to define and establish a measurement model of undergraduate engineering education learning outcomes associated with professional competencies (soft skills) development [18].

The authors used the TTI TriMetrix DNA assessment framework to analyze two populations of students, traditional engineering undergraduates and professional engineers, returning to the university in pursuit of an engineering Master's degree. The undergraduate population contains Freshman and Junior level students. The professional graduate students in the data set work full-time. They are early-career professionals with approximately five years of industry experience. The majority of this population were individuals that were deemed by their employers to be on track to take on leadership positions within their company. For this report, the TTI TriMetrix® DNA assessment was administered online between the fall of 2017 and the fall of 2020, with 251 undergraduates (freshmen and juniors) and 93 professional graduate students.

The focus of this case study was to consider the full data set of undergraduate and graduate (high potential) engineers in an attempt to determine whether we could identify pedagogical differentiating subsets of these students. The first step was to consider the entire data set and, using a hierarchical cluster analysis approach in order to determine a reasonable group of clusters based on the 20 DISC variables. DISC is a behavior assessment tool based on the theory of psychologist William Moulton Marston. DISC centers on four different behavioral traits: Dominance, Influence, Steadiness and Compliance. There are no best styles, and all people exhibit some level of intensity of all four components.

Natural and Adapted DISC Behavioral Styles

A choice was made to use all 20 variables over the smaller sets defined by Adapted and Natural DISC scores only and the 12 hierarchical derived variables based on initial testing of the various sets. Natural DISC represents the behavioral style an individual is born with. There is no best DISC profile, but rather everyone has their own unique style. Adapted DISC represents how one modifies their behavioral style because of life conditions. Most people's Adapted DISC has some change over time, often due to maturation and or some change in life conditions such as transition to college student or working profession. These changes are often minor and not of great significance.

Each data set provides relevant information, yet the full combination showed the most promise in those initial views of the data analysis. See Figure 6 for the final visualization of the clusters. The number of clusters was chosen based on multiple criteria including the WSS method, the silhouette method, and the gap stat method, along with a visual check via the plotted data shown in Figure 6 compared with various numbers of clusters. It was determined via merging of information from the aforementioned methods that the appropriate number of clusters was three.

Cluster Analysis and Three-way ANOVA

Through the process of Cluster analysis and three-way ANOVA this process neatly identified three separate subsets of variables that identified strongly, one with each of the pre-computed clusters of students. It should be noted that it is expected that the 20 DISC and DISC derived variables will likely be significant in the vast majority of the cases considered. After all, these are the variables used to define the clusters based on their collective differences. Table II shows the variables that showed statistically significant differences.

The next question is the directionality of the differences observed in the population means. As an example, if one considers just the names of the variables in the above table, one may be tempted to view Cluster 1 as being unique among the clusters and defined by management skills or leadership when, in fact, it is the case that Cluster 1 is differentiated from Clusters 2 and 3 based on lower scores, not higher. This information is summarized in the score columns in Table II.

The interpretation is as follows: L means the variable in question had the lowest population mean of the three clusters, M means the variable in question had the middle population mean of the three clusters, and H means the cluster had the highest population mean of the three clusters.

This piece of information provoked further interest to see if anything could be specifically found that may account for this information. We considered the population breakdowns. The full population is shown in Table III.

So, we see a 73/27 split between the undergraduate students and the graduate students, with approximately a 60/40 split of Freshmen/Juniors. Table III shows a solidly consistent split in the undergraduate populations with all three clusters showing very nearly the same 60/40 Freshman/Junior split. However, note that the percentage of graduate students consistently increases as we consider the various clusters, with a low of 21% in Cluster 1, to a high of 38% in Cluster 3.

Figure 6: Cluster plot of the data set showing the three clusters.

Table II: Statistically significant DISC variables for each cluster and their associated score (Low, Middle or High).

Cluster 1	Score	Cluster 2	Score	Cluster 3	Score
Conflict Management	L	Theoretical	L	Aesthetic	L
Influencing Others	L	Social	H	Continuous Learning	H
Interpersonal Skills	L	Individualistic	M	Creativity and Innovation	H
Leadership	L	Influencing Others	M	Flexibility	H
Negotiation	L	Negotiation	M	Goal Orientation	H
Teamwork	L	Problem Solving	L	Influencing Others	H
Understanding Others	L			Negotiation	H
				Resiliency	H
				Self-Starting	H

While we can dive deeper into this data and consider things at a more granular level, we can see a few broad conclusions quite clearly. At the minimum, there are three clusters of learners. Given the percentage breakup of the population (roughly, 60-70% undergrad and 30-40% grad) being similar in the three clusters there is no clear indication of level of maturity/advancement in level of studies being the determining factor to put an individual in one cluster or another.

On the contrary, we can argue that most classrooms will have students who could be in any one of these clusters. One can also argue that students in one cluster have a different set of needs from students in another. They will respond differently to different sets of stimuli and will need different motivating factors. The skill development needs for the different groups will be different as well. This means that in a classroom where the mode and means of learning are uniform, whereas the audience is clustered, some portions of this population will be bored, disenchanted, unmotivated and therefore effectively excluded. This is happening in many classrooms today; inherently many instructors realize this but have no means to address this. This is a unique view of exclusivity. Modern technological tools such as IoTs provide us the opportunity to address this kind of exclusivity by innovating new strategies to include all types of learners.

Table III: Population distribution in the three clusters.

	Total Pop.		Freshmen	%	Juniors	%
Total	344					
Ugrad	251	72.97%	148	58.96%	103	41.04%
Grad	93	27.03%				
	Cluster 1					
Total	165					
Ugrad	130	78.79%	78	60.00%	52	40.00%
Grad	35	21.21%				
	Cluster 2					
Total	84					
Ugrad	62	73.81%	37	59.68%	25	40.32%
Grad	22	26.19%				
	Cluster 3					
Total	95					
Ugrad	59	62.11%	33	55.93%	26	44.07%
Grad	36	37.89%				

3. Potential for IOT to Impact the Changing State of Inclusive Education

Engineering technology is evolving at an exponential rate and having a profound impact on industry as the digital age of Industry 4.0 advances. This is true in the classroom as well. Instructors find that traditional approaches for updating content and conventional teaching practices are often ill-suited for incorporating rapid changes. Coupled with that is the fact that learning styles and motivations of faculty and students can be drastically different as they each come from populations that can be as much as 5 generations apart. With an explosive worldwide growth of the use of the internet [19] the use of technology associated with the internet (IoT) to improve the educational ecosystem is growing, urgent and inevitable.

3.1 Promise of IOT

Exceptional teachers get to know their students very well, their habits, learning styles, personalities etc., and can utilize that knowledge and understanding to positively impact student learning. This sort of insight is rare at best, and cannot be expected from all teachers. IoT, the data generated from it, and the machine intelligence developed from that data provides a huge opportunity to improve the current education ecosystem. IoT consists of sensors and actuators, everyday objects that are linked through wired and wireless networks. Data generated from these devices provide tremendous insight into large systems and reveal dynamic information about the world of man and machine. The value of IoT for education lies a lot in the data it generates and how that data can be used to improve the education process. In the previous section the exclusivity problem was identified to be in three broad areas: (a) access, (b) retention, and (c) quality.

Figure 7 shows a schematic of the vision to address these problems. Systems such as card swipes, biometric recognition, video technology, voice and other smart ids, user interfaces, etc. provide the opportunity to reliably track students or potential students and their behavior both inside and outside classrooms. Data generated on individuals can be used in three broad ways. For those who are left out of the educational ecosystem this data in conjunction with a national database will help identify individuals who should be brought into the fold (path shown in light orange in the figure) by identifying who are in the classroom and who are not. It is foreseeable that this task, while enormous in scope, will have to be performed once per student. Country wide efforts, such as in China, to track all its citizens use many of these technologies in the public arena with great effectiveness.

The issues of retention and quality are both shortcomings in the current ecosystem and addressing them has to do with the population who have engaged with the educational world already. Within this population problems can be of many types. For example, individual students may have completely different learning styles and may need different kinds of attention from instructors. Others may not be able bodied or hearing or sight impaired. Also, groups of students demonstrate different learning styles and preferences. For example, some learn better from “How to” videos as they are performing a task, while others need to have a very clear understanding of everything before they start a task. And just like it was described in the previous section, there may be a whole swath of the population who may not have access to good classrooms (or any classrooms at all), good teachers or equipment due to their geographic locations. Meanwhile, the instructor has to assess whether students are achieving an appropriate level of progress. To deal with issues of this nature data analytics and machine learning tools can be used on IoT-generated data to customize education for groups of students who are of similar mindset, as well as individuals (these two types of tasks are shown in light green in figure 7). These activities will need to be iterative and adaptive and have to happen in conjunction with systemic paradigm shift of how students are educated.

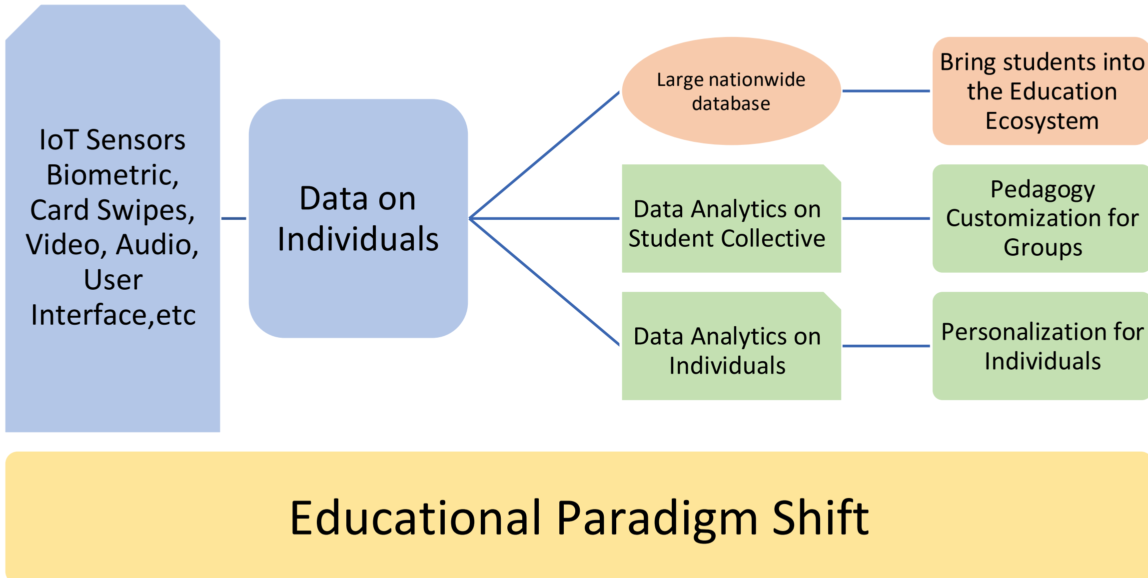

Figure 7: Flowchart to highlight the vision of inclusive education.

The myriad of IoT applications in the world of education can be broadly divided into five categories[20],[21], [22],[6]:

I. Accessibility: Educational programs made available to all
II. Personalization: Education customized to suit individual learners
III. Cost Reduction: Educational programs and materials at affordable prices
IV. Learning Management: Efficient, user-friendly delivery of program
V. Security: Tamper-proof, intrusion-resistant information protection

Figure 8 summarizes the many IoT- based strategies within these five areas that can enhance inclusivity in education. In the next few sections, we discuss each of these categories in detail. Some of the major vendors who are at the forefront of providing these IoT solutions include Google (US), Amazon Web Services (US), IBM (US), Microsoft (US), Oracle (US), Intel (US), Cisco (US), SAP (Germany), Huawei (China), Arm (UK), Unit4 (Netherlands), and Samsung (South Korea).

3.2 Accessibility: Educational Programs made Available to All

1. With the advent of remote, internet-based learning technologies, students are not confined to resources that are in their immediate surroundings. They can access the best resources anywhere in the world. Online platforms such as MIT OpenCourseware [23], Coursera [24], Edx [25], and YouTube [26] now provide students with access to the world's best instructors. Devices or applications such as Siri or Alexa are internet enabled and can be used to stream this educational

material on demand. As IoT technology becomes more routinely integrated into products, new ways to access education becomes ever more convenient. On-demand education is available in common products such as mobile phones, automobiles, kitchen appliances, and tools, etc. IoT is expanding the freedom and flexibility for people who wish to study from anywhere, at any time.

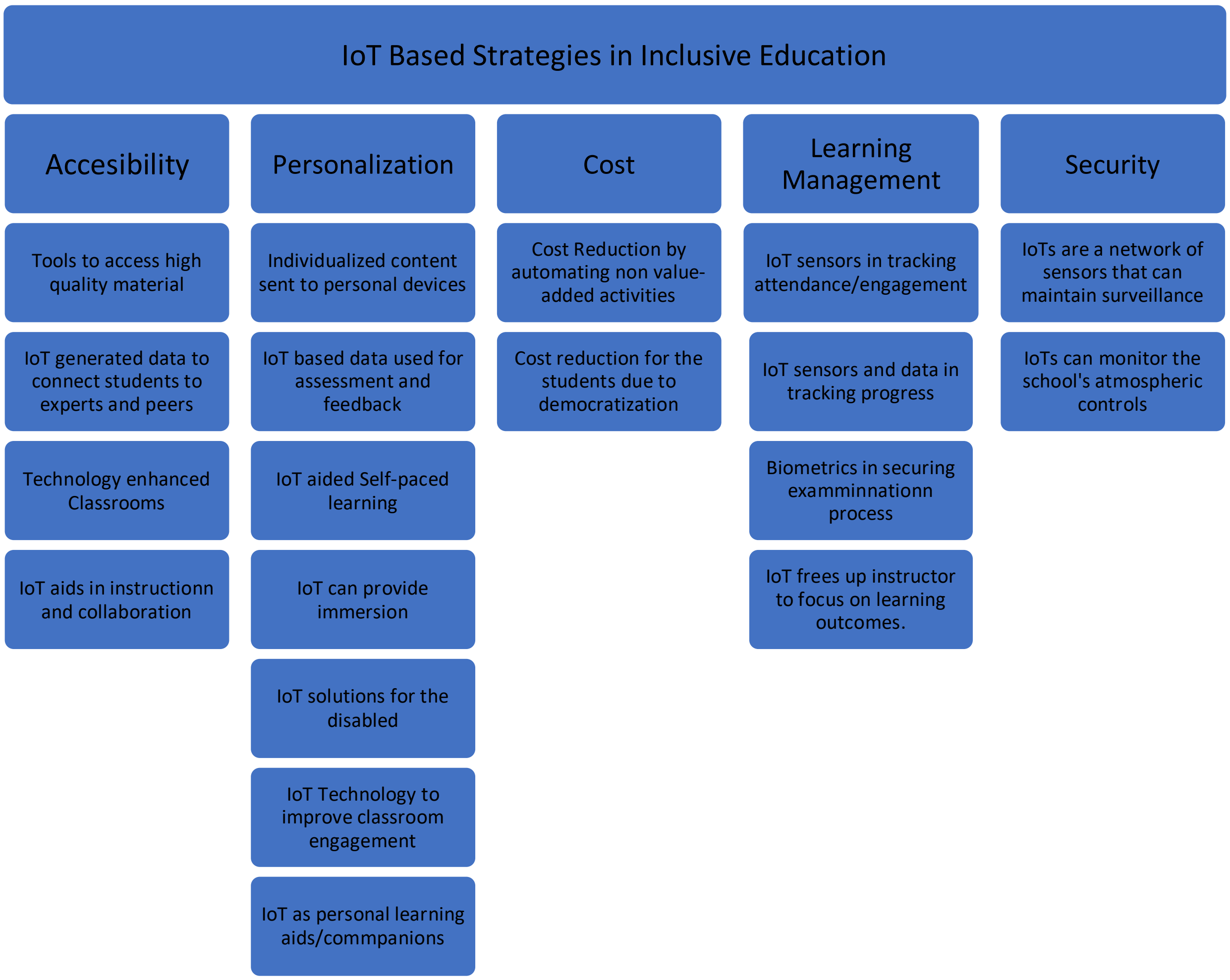

Figure 8: Some of the strategies of using IoT applications to make the world of education more inclusive.

2. IoT enabled data gathering on individual learners can connect a need with a resource. For example, a student learning about history can chat with an archaeologist. Language students can communicate with native speakers via blogs or wikis. IoT creates additional opportunities, such as data on individual students and what they are learning can be used to connect to their peers (locally or across the world) who are at the same stage of learning, to generate meaningful interactions, learning groups, and peer support[22].

3. Technology-enabled classrooms are already here. Instructors are already employing AR (Augmented Reality) [27] to create experiential, virtual learning experiences. For example, a biology class on dissection no longer requires the killing of real animals. In history classes, the students can be in the front seat as historical events unfold. Science students can participate as scientific discovery happens. Medical students, engineers and others in professional programs can practice their skills on human dummies or test rigs which themselves are IoT devices that can simulate realistic response. This way, IOT is able to bring high quality learning tools and techniques in front of all students and is helping make the playing field more uniform.

4. Many IoT technologies are helping make the learning space more efficient and enhancing student access to materials and information. Some examples of current technology include: Smarter Whiteboards, ScanMarker, Smart Environmental Controls, and many forms of Digital Signage [28]. One example of a Smarter Whiteboard is the Bounce whiteboard and associated app from IdeaPaint [29]. This technology replaces current smart whiteboards that only permit one image at a time, before it gets wiped away before you can start again. Bounce [29] saves all brainstorming sessions, answers and notes and stores them in the app where they can be reached at a later date. No longer do students have to scribble down notes from the board. Instead, they can listen and participate, then access notes later through the Bounce app. These notes could be shared further too, with sick classmates, governing bodies, and even parents, if permitted. ScanMarker makes a digital highlighter that allows learners to scan and digitize any object. In most classrooms, notes are made manually and there's not much connection between the books read and the computer a student uses. With a smart device like ScanMarker, an inefficient process becomes efficient. Perhaps the easiest way to a smarter classroom right now is through digital signage. The art of using HD monitors to share content is not new, but is still widely underutilized within education. All that's needed to set it up is an HD monitor with a smart device such as a $35 Amazon Fire Stick and a that can cost as little as $20 per month. The applications are plentiful. Digital signage screens can not only be used as a smart bulletin board but can also be used to share educational content, additional reading and even pop quizzes to keep minds occupied as students wait in the halls.

3.3 Personalization: Education Customized to Suit Individual Learners

1. IoT tools and the data generated from them about individual learners can be used to create special content for students that could be sent to them directly on their tablets and smartphones or other devices. For example, a student whose preferred learning mode (say visual vs. audio) is known, can receive a personalized lesson in the preferred mode once they are identified through biometric identifier or an id reader.

2. With IoT, students can easily access personalized assessment and feedback**.** The development of powerful learning analytic tools allows students to monitor their own progress towards learning goals. Apps like Khan Academy [30] and DuoLingo [31] embed personalized assessment in the learning experience. Learning analytics can identify areas where additional instruction is needed for the student to improve their skills. The ability to self-assess that these tools provide with a Wifi connection enables every student to take ownership of their learning.

3. In reality, students learn best when they do it at their own pace. With IoT, one can do it very easily. However, with new IoT technology that can personalize education, incorporation of hands-on experience and expert examples is easy [6].

4. IoT enables learners to be open towards asking questions because it is individualized [6]. This increases student engagement significantly.

5. One of the most powerful mechanisms for learning foreign languages is immersion [32], whose secret weapon is real-time feedback. When learning French in France, you get real-time feedback from native speakers “for free.” These environments are difficult to recreate outside of countries where the language is spoken. That’s where IoT comes in. Using smart and connected devices ([33],[34]) to determine whether students have made the correct statements or selections in foreign language simulation environments, teachers are able to provide real-time feedback to students and automatically monitor student progress.

6. IoT may prove helpful for students who identify as disabled. Hearing-impaired students may utilize a system of connected gloves and a tablet to translate from sign language to verbal speech, converting sound into written language [28]. Using IoT devices and systems is a constructive way to provide educational assistance to disabled learners.

7. Gamification of object-led learning: There are software products already available that help educate through gamification. One example is the smart Kolibree software that uses a game to teach children how to brush their teeth [33]. The game has 3D motion sensors that track brushing behaviors, that can then be monitored by parents. This data is also then collected to gain an overview of children’s brushing habits as a whole. In the classroom, the opportunity to teach through similar methods, where real world actions are linked and measured, could help students learn faster and in a much more visual manner.

8. Many children who are adversely affected by traditional classroom techniques find that IoT connected devices are able to open doors and streamline their learning abilities. Children with communication challenges often respond extremely positively to tablet technology, and wearables in the classroom can provide instant alerts if a child needs help but cannot verbally describe their issue. Personalized robots [35] and google glass [36] are some of the technologies that have been shown to provide help and comfort in the functioning of autistic children and enable

their learning process. According to Ed Tech Review, "Special needs students also have a lot to gain from this shift to technological means" [37]. For instance, students with impaired vision can be given special cards that are detected automatically and can inform connected devices to display text at a larger font. Through these advancements, the IoT can facilitate equal access to education for all students." Another example is Microsoft's Seeing AI project [38] which can run on the student's smartphone to provide a play-by-play account of what's going on around them. Anyone partially-sighted would enjoy a more inclusive role within their school community.

9. Some additional IoT solutions to help disabled students are:
   a. Screen reader: a text-to-speech application that reads out computer and Internet-related information to assist people who are blind or vision impaired.
   b. Screenmagnifier: a magnification tool to enlarge screen content. Themes: high-contrast themes to allow people with visual impairments to change the colors to a more comfortable setting (such as white-on-black) and increase the size of mouse pointers and text.
   c. On-screen key board: assistive keys enable people with mobility impairments to 'type' by using a pointing device to select letters and words on the Screen.
   d. On-screen alerts: visual messages can appear in place of audible sounds to help people who are Deaf or hearing impaired.

3.4 Cost Reduction: Educational Programs and Materials at Affordable Prices

1. The current model of "teacher centric learning" where a teacher is responsible for a class full of students' learning was never meant to scale well. Majority of the teacher's effort is expended in tasks that are not value-added such as maintaining discipline, taking attendance, and tasks that take a lot of time such as grading, monitoring progress and providing feedback. In order to serve large population of students in this model a large number of qualified teachers are needed and that is quite expensive. In a "learner centric model" the focus is much more on the learner and many of the routine tasks can be done by sensor-augmented devices. IoT devices such as sensors as well as the data generated from these devices can be used for attendance [22], track student progress [22], determine where students are struggling from data analytics [6], etc. In the long run this saves a lot of money.

2. Knowledge and information are available to all for free or at a low cost. Wealth and lack thereof have always been a great divider of people who had access to high quality education and those who did not. Even in educational models where public education was free for students, resources in school districts varied widely between rich-districts and poor-districts. We know all too well about poorer school districts not being able to afford textbooks. Or students who couldn't afford college did not get higher education at all. Now even the poorest students and schools can have access to educational materials at essentially zero cost [22].

3.5 Learning Management: Efficient, User-Friendly Delivery of Programs

1. Research shows that passive listening to lectures in a classroom is perhaps the least effective way of learning. However, that has been the prevalent mode of instruction used universally since that is the most economic approach. One of the structural shifts taking place in education is the move from a knowledge transfer model to a collaborative, information-sharing system. IoT will have a profound impact on the way we teach, because connected and easy access to high quality lessons and lectures free-up teachers from recording and monitoring students, enabling them to facilitate learning rather than merely to regurgitate information. In task-based instruction, students learn-by-doing and teachers assist when needed. IoT systems provide feedback, assistance, and classroom-level monitoring automatically. By signaling teachers for help and by increasing difficulty when necessary, no student falls too far behind nor gets too far ahead—a problem that has always persisted in the classroom [20].

2. IoT applications allow students to track their learning progress and evaluate their performance and results and take corrective action [6],[22].

3. IoT automates processes such as accounting students as present or tardy when the bell rings. For those that don't attend class, teacher or administrator can follow up on them individually through the online system [20],[21],[22]. Students who are performing poorly or needing extra help can be flagged and referred to appropriate personnel for help. Wearable devices will determine when the class is too tired or disengaged and may need a break, and whiteboards will record all notes taken in a class. Smart-microphones may even recognize when a teacher mentions there is a homework assignment due and update students' planner accordingly.

4. Using IoT technology the examination process can be made more efficient. One example is the Examination Zone, where biometric security is used to identify a learner as they log on to an examination system. Once the student has answered the questions, the answers are pushed to a secure server and are also checked to ensure validity and security conditions. This already begins to remove many of the manual processes associated with exams and allows the process to be streamlined and more secure from cheating [33].

3.6 Security: Tamper-Proof, Intrusion-Resistant Information Protection

1. It allows you to keep an eye on the hallways, classrooms or any other room within the school. IoT allows you to get video surveillance of the institution through your smartphone, tablet, laptop or desktop [6].

2. IoT also helps you to monitor the school's ventilation system through your electronic device. That way, you make sure that your students and staff are always well taken care of [6]. IoT applications for climate control, temperature monitoring, and energy conservation in a classroom setting have been in use already. But

they have been taken a step further through applications developed by Bosch. For example, they have used IoT to share information on climate control and energy saving directly into the schools. They have created an image of Einstein in a grammar school in Austria, who would notify students and teachers each time there was a change in atmosphere. The painting would then go on to notify the students how they could adjust their conditions for maximum focus. These types of creative applications are available now and not only improve the efficiency of schools, but teach students at the same time.

4.The Changing State of Inclusive Education - What impact is IoT having?

Early in the first decade of this century Dr. Sugata Mitra, a well-known computer scientist and educational theorist ran an interesting experiment in New Delhi, India [39]. He placed a computer in a "hole in the wall" on a street corner next to his workplace. No instructions were left. Interesting things started to happen. Children from a local slum, who had no prior experience using a computer and no knowledge of the English language, got very curious and started experimenting with it and soon figured how to use it. Not only that, they continued to use it as a learning tool to access information on a variety of subjects as well as learn the English language. This experiment was later expanded in scope and taken into the villages of India and other parts of the world. Dr. Mitra's TED talk [40] on this now famous "hole in the wall" experiment is also quite well known. Apart from things such as the importance of curiosity, encouragement and inspiration, learning by experimentation and trials, his work also shows how technology can be a great equalizer in the world of education and learning. It has been almost 20 years since his first experiment and technology, specifically IoT technology has advanced a lot. We have all the tools in our hands to make learning more inclusive and education more equitable. Learning requires curiosity, access to high-quality information, expert guidance and mentoring, and progress towards desired outcomes. The tools of today such as internet connectivity, IoT and associated data analytics, easy access to information, devices such as Siri and Alexa, tools that can offer information in a variety of ways such as audio, video, print, etc. can easily enable that to happen. Along with that, mentors and experts, even if they are all the way across the world can be available through video conferencing. And the significant capability of sensor technology for data gathering and AI and other techniques of data analytics enables the educators to offer just-in-time, adaptive, dynamic, and personalized education that can meet every student's needs.

We believe that all these technologies put together can be paradigm altering by making education and learning more inclusive for those who are excluded because of geography, physical or mental ability, poverty, or for any other reason. However, in order for this to be successful, the education and learning paradigm needs to change. We are still set in the old ways of doing things that were invented in the age of Henry Ford and his assembly line, and the second Industrial Revolution (Industry 2.0). This is the age of Industry 4.0 and we need an education paradigm that fits the current time, an Education 4.0 [41]. Some of the characteristics of this new educational paradigm should be:

- Flexible Source of Knowledge and Information

- Flexible mode or Individualized learning
- Scalability
- Experimental or Hands-on
- Transdisciplinary
- Just-in-time information based rather than pre-requisite based
- Formative Assessment of skill growth and ability to learn
- Emphasis of acquiring skills rather than knowledge
- Teacher becomes more of a mentor or Coach

The old way of doing things where the same identical template or learning mode used for every pupil cannot be acceptable any more. It leaves too many talents behind or on the side-lines. The current system is very robust, it has survived so long, and those who can fit in can do well in this system too. But the world cannot leave behind all the talents who do not fit in the current learning system, and their numbers are huge. IoT tools [42], [43] to re-imagine and re-design the current educational system are either already available or in development. The question remains, is there the will to change and adapt? We believe the cost of not changing will be unsustainable.

5.Conclusion

Time has come for a collective effort to make education and learning more inclusive. Education is not just for those who can access it easily. Educators and policy makers need to work hard to make it more accessible for those who have been left behind. This segregation of the *included* and the *excluded* can be due to many reasons, physical ability, financial ability, learning styles, and geography to name a few. In this paper, we attempted first to highlight the scale of the problem through a case study on sub-Saharan Africa where a huge swath of youth has been left out because of lack of access and infrastructure. We then presented data to show how a population of students presents three distinct types of learning styles, each with its own unique educational needs.

Technological advancements in the field of Internet of Things (IoT) keeps adding newer and newer applications every day that can be used in very creative ways in the field of education. In this paper we have discussed some of them. We should accept that technological solutions are available to make education inclusive in very meaningful ways. What needs to happen is reimagination of the flexibility necessary to change the paradigm of the educational system. Leaders need to act boldly, make the necessary investments, use technology, and embrace changes so that the large swath of the world population that has been excluded from today's educational system can be included as we move forward.

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