# 21st Century Ergonomic Education
## From Little e to Big E

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Despite intense efforts, contemporary educational systems are not enabling individuals to function optimally in modern society. The main reason is that reformers are trying to improve systems that are not designed to take advantage of the centuries of history of the development of today's societies. Nor do they recognize the implications of the millions of years of history of life on earth in which humans are the latest edition of learning organisms. The contemporary educational paradigm of "education for all" is based on a 17th century model of "printing minds" for passing on static knowledge. This characterizes most of K-12 education. In contrast, 21st Century education demands a new paradigm, which we call Ergonomic Education. This is an education system that is designed to fit the students of any age instead of forcing the students to fit the education system. It takes into account in a fundamental way what students want to learnthe concept "wanting to learn" refers to the innate ability and desire to learn that is characteristic of humans. The Ergonomic Education paradigm shifts to education based on coaching students as human beings who are hungry for productive learning throughout their lives from their very earliest days.

## I. SETTING THE STAGE

The national education reform movement in the USA (US), which is used here as an example of a highly developed country, has not delivered the results envisioned or hoped for when it was launched by *A Nation at Risk* (National Comission on Excellence in Education, 1983). Rather than rising levels of national student achievement to meet the needs of the 21st century, the US reform movement has instead yielded a growing burden of responsibilities being piled upon local educators. Current attempts focused on improving student performance have not resulted in significant gains on standardized tests or on graduation rates, especially for the students who traditionally perform poorly.

Since *A Nation at Risk* there has been an increasing crescendo of calls for reform in the US. Yet accompanying each decade of reform have been numerous reports continuing to document the failures of the nation's schools. There has been an endless progression of fads sweeping through the US schools, each buoyed by inflated claims of its power to reshape education for the better. One novelty follows another, typically leaving only broken promises and dashed hopes behind. The parade of failed *pseudo*-innovations leaves educators and their communities pessimistic about the value of anything new proposed by state or national decision-makers. They are fearful that any new developments and initiatives will again be temporary – here today and gone, if not tomorrow, then in a year or two – eliminated because of lack of commitment or lack of resources or both.

Changing priorities, overlapping as well as conflicting educational targets of achievement and well intentioned but poorly structured local, state, and national programs have produced an ineffective, inefficient, and increasingly irrelevant education system. As one looks across the current educational scene it is possible to identify a continuum of initiatives that can be observed in most US schools. This continuum is made up of at least three general categories: chaos, revitalization, and the beginnings of a transformation. Some characteristics of each are summarized below.

### A. Chaos

The first category of the continuum, "chaos," embraces most reforms entering classrooms from "the outside". These initiatives may be mandated by politicians, regulators, education administrators, or well-meaning reformers. For example, the initiatives in the US in mathematics, English and science for quasi national standards are creating dilemmas for school districts. Questions being raised include: How do we disseminate the standards? How can we prepare enough teachers quickly enough to teach the new standards? What sort of pedagogy will be most effective and

how to implement it? How can teachers prepare their students for the tests that are to measure student learning of the new standards? How do we evaluate teacher effectiveness if we do not use the typical value-added measurements? The reforms have not only sparked chaos in local schools but have actually been counterproductive. They have left parents, local policymakers, and especially teachers leery of investing in new ideas because the likelihood of failure is far greater than of success. Those who recognize the chaos get discouraged and stop fighting it.

Meanwhile, newcomers keep emerging certain that the problems of schools are easily solved and they jump in to start a new round of unrealistic reforms. No one knows what should replace the current poorly functioning system or how to phase in a replacement such that genuine improvement takes place despite the innumerable barriers. Typically these new reforms do not result in sustained student achievement. Panaceas such as more subject matter courses in college for teachers, more seat time for students, or subject specialists in classrooms do not address systemic problems of inadequate salaries, poor working conditions, inadequate training in how to teach unmotivated children, or negative impacts of life in current schools on promising young teachers. As Michael Fullan (2007) states "It has become more obvious that the approaches that have been used so far to bring about educational change are not working and cannot work" (p. 299).

## B.    Revitalization

But while external reforms are being inflicted on schools and teachers, many educators at the local level are creating a second kind of intervention. They are creating their own innovations to solve the problems they have identified as most pressing in their individual schools and classrooms. The innovations are "revitalization" reforms and have been implemented by the people who created them to meet a personal need locally. They may be limited to a single classroom when a teacher discovers the most effective way to engage the studentstechniques that may have been gained through participation in workshops, collaborative conversations with other teachers, or trial and error in the classroom. Local initiatives demonstrate enough success to energize and revitalize local attempts to improve education, even in the face of reforms imposed by outside authorities. However, these reforms typically result in incremental changes and are rarely recognized or widespread. Furthermore, there is typically little research to demonstrate just what makes them successful.

There are also some revitalization reforms that are more widespread than a single classroom. They may have been the result of state or nationally funded reforms that have demonstrated success in numbers of schools, even nationally. Although these reforms in schools may not always demonstrate the integrity of the original design, they have had staying power because of the engagement by committed program developers and teachers. Examples of such reforms in the US include: Success for All (Slavin, 2011, 2014), Reading Recovery (Clay, 1993, 2005; Lyons and Pinnell, 2001), Physics by Inquiry (McDermott and the Physics Education Group, 1995), Cooperative Learning (Johnson, Johnson and Holubec. 1994; Johnson and Johnson, 2014), National Writing Project (National Writing Project, 2014), and Project Lead the Way (PLTW) (2014). However, many of these reforms rarely surpass inclusion in more than a 1000 of the hundred thousand schools in the US, and even with their limited expansion there is little to ensure integrity with their original design. However, such reforms do provide teachers and schools the opportunity to institute changes in classroom structure and instruction that could lead to more student engagement.

## C.    Transformation

As locally effective as school or district revitalization reforms may be, they typically are not able to effect state or national change. There need to be sustainable, scalable interventions that enable improvements in learning for all students. Such interventions can be referred to as "transformations" and imply new kinds of structures and standards of performance. Exceptional revitalization innovations currently found in individual teacher's classrooms, in schools led by exceptional principals, and in districts led by exceptional superintendents (our use of the American nomenclature is not important here) may offer promising ideas for transformation. Bold experiments are called for "that generate new and powerful forces, including, for example, teachers energies and commitments unleashed by altered working conditions and new collective capacities, and students' intellectual labor in collaborating with other students to do the work of learning" (Fullan, 2007, p.299). However, these need to be integrated with other innovations in order to have widespread impact. With time, educational transformation could be accelerated to spread over entire countries and internationally through competition among innovations.

Although the details of the classification are tentative and incomplete, it offers some guidelines for assessing programs. It would be desirable to reduce unproductive activities of the kind listed under **chaos** and make progress

towards **transformation**. For example several of the "given" traditional ways for schooling in the US are only historically contingent patterns from the beginnings of the 20th century, which currently could be challenged. These patterns include: the mandate for twelve years in school, the selection and arrangement of the curriculum, and the academic credit system. Sheppard (2005) specifically points out that the academic credit system became antithetical to the ideas of progressive education as it expanded beyond the administrative and logistical issues for which it was designed. These and other historically contingent patterns that are no longer productive for the 21st century should be open to challenge. However, recognizing that transformations may take many years, shorter-term (three to five years) improvements in education are possible with support for revitalization programs across more schools.

### D.    Towards Harmony

The current focus for both, national, state or regional funding is on expanded rigorous testing to determine the degree of success in teaching. Unfortunately, what teachers have long known, what gets tested is what gets taught. It does not matter whether the material is actually preparing students for careers or higher education or a fulfilling life. For example, as noted in a 2012 Ohio newspaper the emphasis has been on "test scores above learning, ratings above reasoning, and appearances above academics." The editorial asks "Is that the best plan we have to develop students who are prepared to succeed in a complicated, competitive global society?" (Cincinnati Enquirer, 2012). And paraphrasing W. Edwards Deming, "...quality can't be achieved through inspection and sorting out defectives, but rather by improving the process..." (Lillrank, 2010).

Confidence in the ability to actually reform education continues to erode. Part of the problem is that our education systems are complex and messy. The attempts that have been made to understand those isolated pockets of success that are always selected as examples of what can be accomplished have never been able to account for the inability to bring these to a scale beyond a few thousand schools. The names may stay but the students rarely experience the success of the original model (Education Trust, 1998, 1999; Grissmer and Flanagan, 1998).

Research on what impacts student performance continues to be ambiguous. There are significant variations in research design, problems with establishing control groups, and lack of clarity of how teacher preparation and student achievement and performance are defined. And there is little research on the interactions of the many variables that impact the delivery of quality teaching and learning. There is also a lack of historical research on the continuity and change that has impacted education.

A new paradigm is needed based on the establishment of principles for learning and rules for teachinga set of explicit principles that govern the processes of learning and rules that serve as a norm for guiding the process of teaching. These rules and principles are not susceptible to arbitrary decisions and are increasingly recognized as flowing from and incorporating how the brain develops and learns as the product of millions of years of evolution (Fields, 2010; Gladwell, 2008; Dawkins, 2004) and how it can operate most recently in a free society (Dewey, 1997). Some of these principles and rules must support the freedom of all students to learn the way they are capable of learning, help students realize what this means in terms of personal freedom and individual responsibility, and safeguard the freedom to choose, prevent abuses, and respond to changing contexts.

The new paradigm of Ergonomic Education proposed below would allow for many competing ideas to fuel students wanting to learn. However, these ideas will only be in harmony as long as there is agreement on the principles of learning and rules of productive teaching studied, recognized, developed and applied by the teachers. With freedom of choice in the hands of the learner and rules of productive teaching applied by the teacher, new knowledge, innovation, and creativity can be fostered to address dramatically changing social and environmental contexts. There are reasons to believe that harmony of new system building and functioning will emerge from the recognition and adoption of the new paradigm of Ergonomic Education.

### II.    HISTORY CEO

To most people history consists of dates and records of events and individuals – a war, an election, a coup, the birth, life and death of notable personae, and more recently, the lives and contexts of the general population. In contrast to the emphases on specific dates and events, individuals or populations, *ongoing processes of change* throughout history, have had far more profound impacts on people's daily lives than do most isolated historical events.

Historians understand that "the unique and the specific matter as much as the universal; that context and initial conditions matter; that the world is more complex than what is assumed in variable-controlled laboratory experiments;

and that predictions are at best problematic" (Staley, 2010, p. 35). However, although messy complexities and idiosyncrasies characterize the study of history, it is still possible to draw inferences that illuminate useful knowledge (Landes, Molkyr and Baumol, 2012, p. 528).

Similarities and commonalities in development can be observed in the midst of the differences that separate historical events. These similarities and commonalities can aid in establishing categories and analogies that provide structure for understanding the flow of history. This flow of history encompasses *processes of change over extended periods of time.* A perspective on the more profound of the ongoing processes of change that have had and continue to have significant impacts are reflected in the phrase: "History CEO"History Constrains, Enables and Organizes. Significant change processes that span centuries can be identified and have implications for the future. Understanding the driving forces and trajectories of these change processes may help society be better prepared to meet the challenges of the 21st century. Each change process of History CEO, " in and of itself is indeterminate, always contingent on numerous factors and usually compatible with movement in diverse directions" (Eisenstein, 2005, p. 333). One notable and exceptional example of such diverse paths is the contrast b etween the impact of the printing press and printing in China compared to the impact in Western Europe, particularly in education, over centuries.

More than 1300 years ago China developed and used printing on a large scale, but only for a limited time. Initially printing was oriented to religious materials and was encouraged by a woman, a prominent supporter who became an empress. Religious beliefs embraced by the empress *enabled* the spread of printing. However, soon after her death, printing declined and the process was ignored for two centuries. According to Barrett (2008) "Sheer misogyny was undoubtedly a factor in this, but, dynastic politics, religious rivalries, vested scribal interests, elite snobbery, and even a whiff of xenophobia also played a part to a greater and lesser degree" (Introduction and Acknowledgements). All these conspired to *constrain* the spread of printing, despite the initial enabling by the empress.

In contrast to the history of printing in China, Elizabeth Eisenstein (1980) in her two volume ground-breaking history of printing in early Western Europe has identified a systematic, centuries-long, change and growth for what she has called "the print culture". Significant and irreversible changes were brought about in Europe following the "invention" of the printing press by Gutenberg (c 1450).

In her book *The Printing Press as an Agent of Change: Communications and Cultural Change in Early-Modern Europe* (Eisenstein, 1983), Eisenstein explains the now-forgotten constraints that were faced by people who had to make do with the oral and scribal culture that existed prior to the introduction of printing. Because books were very scarce, most individuals were "constrained" from gaining knowledge from documented sources of that time. Libraries, which were the repository of written materials, were few and literally geographically out of the range of most individuals. Furthermore, the scribal copying process led to repeated and newly introduced inaccuracies over time.

As printed books became more accessible, they *enabled* the flow of information and the more rapid organization and duplication of data. Multiple copies with identical content were more easily produced, eliminating unending hours of labor and concentration required by scribal copying. The use of books inspired an increasingly widespread variety of activities not possible or even imagined prior to the existence of the printing press. However, it took more than a century and a half after Gutenberg's first publication of Bibles for a "print culture" to emerge (Eisenstein, 2005).

The centuries-long build-up of activities associated with books both *enabled* and *organized* an increasingly diverse range of applications. Eisenstein's examples of advances in print communications led to changes in religious cultures and significant developments in early science, especially astronomy. The proliferation of books also resulted in a paradox of censorship. Banning certain books *constrained* the dissemination of ideas (particularly those viewed as threatening to religious canon) in some quarters while simultaneously *enabling* the printing of those same books in other quarters specifically so that the controversial ideas could be further examined (Eisenstein, 2005, pp. 209-285).

Although Eisenstein comments that there was undoubtedly an impact on thinking and learning as books became "silent instructors," carrying their message farther than any public lecture, she does not examine the "print culture" that became embedded in education. Furthermore most educators today do not recognize the considerable significance of the centuries-long impact of the printing press and printing on the history of education.

In 1657, two centuries after Gutenberg introduced the printing press, John Amos Comenius, a Czech Moravian teacher, educator, and writer completed his *Didactica Magna* (*The Great Didactic*, 1657, originally published in Latin in Amsterdam) "setting forth the whole art of teaching all things to all men" (Comenius,1992, Cover and Title Page). His book advocated universal education for both boys and girls, teaching in the vernacular, the use of textbooks, the development of graded schools, pacing of instruction, and specific roles for universities.

In Chapter XXXII Comenius (1992) introduces the "universal and most perfect order of instruction" (pp. 287-294). After a brief introduction to the process of printing, Section 5 of the chapter provides analogies of teaching to the printing press where "we might adapt the term typography' and call the new method of teaching 'didachography' " (p. 289). He goes on further to describe the following:

> "Pursuing this analogy to the art of printing, we will show, by a more detailed comparison, the true nature of this new method of ours, since it will be made evident that knowledge can be impressed on the mind, in the same way that it's concrete form can be printed on paper" (p. 289).

> "Instead of paper we have pupils whose minds have to be impressed with the symbols of knowledge. Instead of type we have the class books and the rest of the apparatus devised to facilitate the operation of teaching. The ink is replaced by the voice of the master, since this is what conveys information from the books to the mind of the listener; while the press is school discipline, which keeps the pupils up to their work and compels them to learn" (p. 289).

Comenius continues his analogy of comparing students to paper that is properly prepared and pressed using ink:

> "Similarly, the teacher, after he has explained a construction and has shown by examples how easily it can be imitated, asks individual pupils to reproduce what he has said and thus show that they are not merely learners, but actually possessors of knowledge" (p. 293).

Section 26 includes discussion of end of year examinations which were to be graded by inspectors. These examinations were necessary to test the students' knowledge ensuring that the "subjects had been properly learned" (Comenius, 1992, p. 293). In 1658, Comenius published *Orbis Pictus* or *Orbis Sensualium Pictus* (*The Visible World in Pictures*) (Comenius, 1887). Each page has an image illustrating something having to do with the natural world such as botany, biology, zoology, religion, human activities. Accompanying each image are descriptors written in the vernacular (German) and Latin. *Orbis Pictus* became a popular children's textbook and the model for classroom instruction and was translated into many Western European languages by the 1700's.

By the mid-19th century Comenius' model of education and instruction had been adopted by most of Europe and the US. It provided a uniform structure that could address the increasing need of educating more and more children with fewer teachers per pupil, providing common materials and common curricula across a nation's cultures. It also met the workplace needs of the technological and manufacturing expansion of the industrial revolution.

In 1892, on the three-hundredth anniversary of Comenius' birth, there were many celebrations of his work in the US. In the *National Education Association Proceedings* for 1893 there were several essays noting Comenius' impact:

> "We have found in Comenius the source and the forecasting of much that inspires and directs our education now.What is commonplace today was genius three hundred years ago" (Hark, 1893, p. 723).

> "The place of Comenius in the history of education, therefore, is one of commanding importance. He introduces the whole modern movement in the field of elementary and secondary education. His relation to our present teaching is similar to that held by Copernicus and Newton toward modern science, and Bacon and Descartes toward modern philosophy" (Butler, 1893, p. 728).

As the histories of the adoption of Comenius' vision for schooling systems globally are examined, commonalities are expected that illustrate when history constrained, enabled or organized these systems.

Today, 121 years since the celebrations in 1892, most education systems and modes of instruction are still embedded in the print culture of 1657. The still widely used practices of relying on textbooks for conveying knowledge and then assessing learning with regurgitation of information via multiple assessments that are not informative is outdated. The technology of the internet has far outpaced the printed textbook as a means for sharing information and gaining static knowledge. And measures of performance are inadequate and require development. We believe the new paradigm of Ergonomic Education will refocus efforts on more productive teaching and learning by taking into account in a fundamental way the reasons humans want to learn and how they benefit from learning. The section, *Why* **e** *to* **E**, expands on the importance of changing the current educational paradigm to meet the demands of today and be prepared to adapt to the demands of the future.

The focus on the print culture illustrates both a paradigm shift that occurred from the scribal culture to the print culture and the persistence of an education culture that has been immune from widespread significant change. In contrast, science, technology, and business are conducted very differently today compared to the 1600's. What can be learned from the constraining, enabling, and organizing principles that have impacted their histories? How might these examples contribute to understanding the challenges of education reform?

For example George E. Smith (2009), a historian of science and a philosopher of science, has placed on-line, http://www.stanford.edu/dept/cisst/visitors.html, "Testing Newtonian gravity then and now." The material reviews the historical process of over *three centuries* of testing and simultaneous refinement of calculations in Newtonian gravity as it applies to the solar system. He documents the increasing variety of sources of gravitational potentials that have been included, from additional objects discovered in the solar system to later Einstein's corrections required by special and general relativity. But attention to such long-running historical processes as the emergence of the print culture or the testing of Newtonian gravity still seems to be rare.

Thomas Hughes (1983), a historian of technology writes in *Networks of Power* about the expansion of the electric power system from small intercity lighting systems of the late 19th century to the regional networks of the 1930's. He identifies phases of (1) inventor-entrepreneur, (2) technology transfer, (3) system growth and reverse salients, (4) momentum and contingencies, (5) evolving systems and planned new ones. These processes mirror the processes expressed by our History CEO. Hughes framework enables him to compare the development of the electric power systems in the United States, Germany, and England. The comparisons along with their contextual peculiarities illustrate the differences in resources, organizational structures, political climates, economic practices, cultural preferences between regions as well as nations. The emphasis is on the multifaceted complexity of systems and what impacts changes over time.

Landes, Molkyr and Baumol (2012) edited *The Invention of Enterprise: Entrepreneurship from Ancient Mesopotamia to Modern Times.* In contrast to many current books focusing on what could be called "how to be an entrepreneur," Landes, Molkyr and Baumol wanted to study entrepreneurship and its relationship to economic growth from historical accounts. In 17 chapters this book describes the socio-technological culture in specific periods. Despite variations due to context, commonalities in the development of entrepreneurship across the centuries could be identified and provide useful knowledge that the editors believe have immediate applications (pp. 527-528).

Peter F. Drucker (1985) also provides a historical account of entrepreneurship in his book *Innovation and Entrepreneurship.* From an examination of both modern and historical inventions, including inventions of new organizational system structures, Drucker identifies seven sources of innovation (1) the unexpected; (2) incongruities; (3) process need; (4) industry and market structures; (5) demographics; (6) changes in perception; (7) new knowledge. He has identified patterns that again have repeated themselves over time in a variety of contexts.

Rather than providing a historical narrative portraying chaotic and unpredictable interactions of many different individuals and events, always in the context of a particular historical setting, the above texts search for patterns that might be connected through space and time. They are particularly interested in patterns that will permit a better understanding of the evolution of historical events that are reflected in today's environment. These patterns may constrain, enable, and/or organize cultures, technologies, political entities, etc. over centuries. History CEO attempts distill these patterns in a way to help understand the predicaments of the current education system. Gaddis (2002) recognizes the importance of patterns in history and of "fitting it all together" (pp.48-49). He does not explicitly address long-running processes of change that could exist in the historical record. However, he introduces many metaphors comparing how one does history to how one does scienceparticularly the historical sciences of astronomy, geology, and paleontology – all of which deal with very long running processes of change.

Significant change processes spanning centuries and multiple disciplines can be identified. History CEO offers a vocabulary for categorizing these processes into a coherent framework. The framework is context dependent, has independent and interdependent variables, is open to positive and negative (Constraining, Enabling, Organizing) feedback loops, and can illustrate the continuity of the change processes. The problems of education are both content specific and interdisciplinary, they are economic and social, and they have historical roots and result from the latest reforms. Comparisons of the processes that dominate the success or failure of socio-technological and socio-cultural systems thus have the potential of providing insights into current education problems and ideas for transformation.

However, time and expertise are needed to collect, analyze, and synthesize data. What to do in the meantime? Where to begin? There are sufficient though limited examples of education successes that could provide the seeds of the new paradigm of Ergonomic Education. Engineers, specifically ergonomic/human factor engineers interested in education as a foundation of the structure and function of society could provide the impetus for a new approach for understanding the most pressing problems of education. As problem solvers they have been trained to achieve

specific results in complex environments with available resources. Would they be able to analyze the notable education successes and failures and subsequently design and produce a transition process that would lead from the current education system to the Ergonomic Education system of the future?

## III.    A ROLE FOR ENGINEERS

In order to address a systems approach to educational reform, Wilson and Barsky (1999) proposed that the six roles of teacher, principal, student, district administrator, consultant, parent and the community, involved in educational change as described by Fullan (1991), needed to be expanded. Wilson and Barsky described a role for engineering research based on an analysis of Reading Recovery (Reading Recovery Council of North America, 2014). Unlike most reforms, Reading Recovery has been successful in the US for over a quarter century. It is an integrated system that has maintained its integrity yet has so far not realized its scale-up potential. It was proposed that the introduction of engineering research would be able to reverse engineer the components contributing to Reading Recovery's success and introduce an R&D mindset that would lead to future expansion.

Scientists are concerned with understanding how the natural or biological worlds work, engineers are concerned with problem-solving. Yet both of the disciplines share centuries of development contributing to the knowledge and practices of today. In contrast school improvement research only began a sustained build-up in the 1960's (Fullan, 1991) and school improvement/educational reform appears intellectually fragmented and not systemic.

The evidence that an engineering research discipline could significantly impact education reform is based on the experience with discipline-based research in the sciences, particularly physics (Arons, 1990; McDermott and the Physics Education Group, 1996). The recent report by the National Research Council (2012), *Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering*, emphasized the need for this continuing research which complements the work in the cognitive sciences by introducing specific attention to the disciplines' priorities, knowledges, worldviews and practices. It advocates the adoption of evidence-based teaching practices to improve learning outcomes for undergraduate science and engineering students. However, what constitutes the "evidence" depends on the education paradigm. In order for the Ergonomic Education paradigm to be realized, there must be evidence that it is more successful than the current paradigm in creating an environment of productive learning.

The engineering disciplines are poised to accumulate the evidence required through their understanding of historical precedents (e.g,. aircraft manufacturing: Vincenti, 1990; Newman and Vincenti, 2007), knowledge of design (e.g., aircraft evolution from the Wright Brothers to the Boeing 777 and Airbus: Vincenti, 1990; Perrow, 1999; Petroski, 1996, 2006), processes of change (e.g., failures of designs in air transport, bridge building, nuclear power plants: Perrow, 1999; Petroski, 1996, 2006); the role of constraints (Perrow, 1999;Petroski, 2006) and reverse engineering. Ergonomics and Human Factors Engineering in particular have "a unique combination of three fundamental characteristics: (1) they take a systems approach (2) they are design driven and (3) they focus on two closely related outcomes: performance and well-being" (Dul, Bruder, Buckle, Carayon, Falzon, Marras, Wilson and van der Doeler, 2012, p. 4). And they bring a "...holistic, human-centered approach to work systems design that considers physical, cognitive, social, organization, environmental and other relevant factors." Karwowski (2005, p. 437). Karwowski goes on to point out that organizational ergonomics is concerned with the optimization of socio-technical systems, including their organizational structures, policies and processes.

One can ask if the ergonomics/human factors engineering disciplines are willing and interested in accepting the challenge of bringing about a transformation in education which could address the concerns raised by Dul, Bruder, Buckle, Carayon, Falzon, Marras, Wilson and van der Doeler (2012) that "Human factors/ergonomics (HFE) has great potential to contribute to the design of all kinds of systems with people (work systems, product/service systems), but faces challenges in the readiness of its market and in the supply of high-quality applications" (Abstract). However, if the ergonomic engineering system design were applied to change educational systems and showed some promise for overcoming the roadblocks inherent to Comenian design, ergonomics/human factors would certainly get a firm hold in broadly understood contemporary professional culture as a resource of great importance.

## IV.    WHY e TO E

The issue of education in the 21st century was an important subject of the first STHESCA conference in Krakw in July 2011 (STHESCA, 2011). Preparations included a seminar also held in Krakw in November 2010 that served

the purpose of defining a starting point for discussing the subject of science, technology, and higher education in contemporary society (Glazek, 2011). The proposed starting point obtained the working title "**e and E**." Lower-case, or small **e** denotes the contemporary world-wide system of education rooted in the design by Comenius from the 17th century (Comenius, 1992). Upper-case, or big **E** denotes a system on a par with contemporary needs.

The table below gives examples of features of **e** that, in comparison with features of **E**, appear already outdated. By the visible contrast, these examples also illustrate that improvement of **e** does not automatically lead to creation of **E**. An explanation of the entries in the table is provided below.

TABLE I: Examples illustrating differences between systems **e** and **E** (Glazek, 2011). Explanations for the entries are provided below item by item.

| nr | e | E |
|----|---|---|
| 1 | subject matter | person |
| 2 | curriculum | context |
| 3 | focus on student weaknesses | focus on student strengths |
| 4 | separation of values from subject | natural connection of subject with values |
| 5 | one-size-fits-all testing for grades | individualized informative assessment |
| 6 | passing exams | performance |
| 7 | Comenian system | post-Comenian system |
| 8 | lack of accountability for learning | accountability for learning à la RR |
| 9 | teaching according to age | individualized teaching, life-long |
| 10 | no self-correction system | systematic self-correction system |
| 11 | compulsion | one's will |
| 12 | out of focus | life-long brain development |
| 13 | out of focus | ten thousand hours |

1. System **e** is focused on teaching subject matter, whereas **E** is focused on educating a person in the context of a subject.

2. In **e**, the dominant form of teaching is specified by a curriculum independently of the context of students' lives. In **E**, a context important to students is a natural stimulus for learning important concepts.

3. In **e**, students are punished if they do not know, do not understand, or cannot do something, until they fulfill the requirements, even if only superficially. In **E**, students improve upon what they are good at, and this is how they notice new elements and directions worth studying.

4. In **e**, teaching subject matter is disconnected from teaching values and building character. Natural sharing of useful information about the world among people in a group in **E** replaces destructive competition (Bok, 1987) and teaches principles of understanding in making decisions and handling resources.

5. One-size-fits-all testing for grades in **e** is replaced in **E** by providing feedback regarding individual progress in skill acquisition.

6. Testing of short-term memorizing "to get credit" in **e** is replaced in **E** by assessment of student performance in practice, akin to how skills of all other members of the system **E** are assessed (Drucker and Maciariello, 2008).

7. Comenius designed the process of teaching students in **e** as analogous to printing books in a press, while **E** fulfills contemporary requirements (Drucker, 1993).

8. Reading Recovery (Reading Recovery Council of North America, 2014) has a system for monitoring teachers' work in terms of their students' progress in acquiring skills. This is worth studying as a candidate for use in E; there is no such system in **e** (Kenneth G. Wilson, personal communication).

9. **e** functions like a production line ordered according to age, while **E** accounts for differences among students, enabling them to develop over the lifespan (Drucker, 1993).

10. **e** becomes outdated and fails, having no system of self-correction, while **E** is by definition being created so that it changes in agreement with the needs of its clients (Wilson and Daviss, 1994; Wilson and Barsky, 1998).

11. **e** is based on compulsion, and **E** on students' will to learn (Glazek and Sarason, 2006) in agreement with the hypothesis (Glazek, 2008) that processes of learning based on will are those that lead to true learning, associated with changes in structure and functioning of the brain and other body parts.

12. In **e**, the human brain is treated in practice as a device ready for one-time programming, while in **E** as an organ that grows and changes throughout the lifespan (Fields, 2010; Dawkins, 2004).

13. Ten thousand hours is the amount of time of deliberate practice required for reaching an expert level of performance (Ericsson, 2004; Gladwell, 2008) and a teacher needs this much deliberate practice to become a good teacher in **E**.

The explanation of number 7 in the Table says that a sketch of specifications for system **E**, congruent with the direction of development of the contemporary world, has already been drawn by Drucker (1993). During Drucker's nearly century-long life he actively studied the practice of management processes involved in the transition of the most-developed countries from domination of a manual work force through instruction to domination of a workforce characterized by mental work based on values, knowledge and skills. Specifications for the emerging system **E** along with predictable mechanisms of creating, principles of measuring (different from the ones applied in e), and methods of improving **E** by new generations until **e** is almost completely eliminated (probably still in the 21st century), form a list of challenges for ergonomic engineers. These will be engineers who out of respect for human factors are willing to engage in redesigning education for the world to have a future.

Suppose that inhabitants of the most-advanced countries cease to accept systems of type **e** and learn in them less and less effectively, while the systems of type **e** enriched with new knowledge and technology continue to be very effective in developing countries. A question arises: Is not a change from **e** to **E** in the leading countries a necessary condition for their continued fulfillment of this role?

## V.   ENGINEERING BY KIDS

It is clear from our outline that the task of changing education is not to be completed quickly, even if the change is a necessary condition for continuation of development of democratic social systems. The cohorts of ergonomic engineers will have to engage in such tasks over many generations. To educate the required generations of capable engineers, one has to involve candidates as early as when they are children so that they will later have a chance to excel over time in systemic handling of extremely complex processes of learning. If people continue to apply systems of type **e** to educate engineers, there is no chance that the alumni will develop the new system **E**. In order to educate engineers who will possess the needed values, knowledge and skills one has to switch from teaching kids according to the principles of engineering **for** kids (look, kids, you ought to do this or that) to the principles of engineering **by** kids (look, kids, you know the problem you face, design a solution).

An illustration of the paradigm shift from **e** to **E** is provided by the following which incorporates principles of the scouting movement. There is a situation at a scouting camp where one group of scouts is separated from another by a river. They conceive of a bridge and get it built. Instead of imprinting minds in a classroom for engineers, knowledgeable and skillful coaches help students design and build a bridge and de facto some of them become seriously interested in engineering. In contrast, a teacher in a classroom could explain to students who sit at their desks how carpenters work on a bridge. This example does not need further explanation in order to catch the attention of serious human factor thinkers whose intention is to make the human learning as ergonomic as it can be.

There exists a great deal of information about the principles and functioning of youth organizations that provide members with the values, knowledge and skills they need. Poland has a particularly rich tradition in this respect because of the long national struggle for freedom. Unfortunately, the available sources are practically solely available in Polish. For completeness, two examples are Janowski (2010) and Kamiński (2013). In addition, contemporary Polish examples of the role that scouting experience can play in producing leaders of great merit include Michał Kulesza, (Wikipedia, 2014) who engaged in scouting in his youth and later designed the democratic government system for Poland after Solidarity took power from communists. An example from the US is provided by Frances Hesselbein (Hesselbein, 2011). She led the Girl Scouts of the US and helped members of the American army leadership understand the principles of education needed for soldiers and officers.

One should also note the great need for the education of managers in values, knowledge and skills stressed by Joseph Maciariello (Maciariello and Linkletter, 2011). This concerns not only the management of engineering but quite generally high level management in all types of organizations that comprise society. Maciariello stressed the

lack of required education for managers as the key reason for recent world crises. The references provided in this section substantiate a link between the need for Ergonomic Education and the well-being of society on a large scale that actually originates in how kids are educated, with scouting providing examples. These examples are also supported by the dialog between Drucker and Albert Shanker, the late president of the American Federation of Teachers (Drucker, 1990, pp. 132-138).

The ergonomic principle of designing the environment to fit the user instead of being content with forcing the user to fit the environment provides engineers and engineering education with the opportunity to engage with the big **E** paradigm. These engineers can become leaders of the new paradigm. The ergonomic perspective of the human condition is here viewed as capable of becoming a basis for the new educational design, provided that the engineers: (1) recognize the principles of productive learning; (2) adhere to the spirit of performance defined by Peter Drucker; (3) incorporate Drucker's principles of management in organizing their new system; and (4) manage the practice of parental support for teacher initiatives in building the new system of engineering by kids. Children and teachers, with support of parents, learn the principles of ergonomic engineering through and in collaboration with qualified engineers. They experience engineering as a vital element of a rational approach to the human condition in a highly developed society. The reason for calling this section Engineering **by** Kids, is that the students are self-motivated to learn, are carefully informed by their coaches about the progress they make, and are helped by coaches in discovering that they need to learn more.

## VI.  CONCLUSIONS

The paradigm shift from **e** to **E** for education is based on the history of science, technology and society (e.g., Hughes, 1983; Smith, 2009) and the millions of years of biological development supporting the current learning abilities of humans (e.g., Dawkins, 2004; Fields, 2010). The new paradigm, big **E**, brings the current condition of educational chaos to a transition and transformation that recognizes the human condition of wanting to learn.

Ergonomic Education focuses on student strengths not weaknesses, it emphasizes the context of learning and not a fixed curriculum, it is not constrained by age-graded classes, and it envisions a self-correcting system for life-long learning. In Ergonomic Education the disciplines are no longer dictated to students but are discovered, practiced and developed by each new generation of students as they develop their strengths both as individuals and as part of a team. It incorporates the concept of productive learning (Glazek and Sarason, 2006) and Drucker's (Drucker and Maciariello, 2008) principles of the spirit of performance and continuity, embodied in the pattern of practice in Engineering by Kids. It is a system that takes a new approach to education by engaging students of any age in building their learning habits through what they want to learn and helping them to learn to benefit from deliberate practice (Ericsson, 2004) as they enter and develop the world of values, knowledge and skills.

The Ergonomic Education paradigm shifts to education based on coaching students as human beings who are hungry for productive learning throughout their lives from their very earliest days. All students, regardless of age, are helped to learn in a system formed by competent educators operating within a new organizational structure. Ergonomic engineers are uniquely qualified for designing and building such a functioning system of big **E** and continuing to make adjustments to improve the system to meet the individual learning needs of students and groups of students as they strive to learn new knowledge and develop social skills.

In addition to the direct impact of **e** to **E** on education, we propose that this is the path to Drucker's (1993) concept of continuity in a global society of organizations where continuing economic growth, world-wide stability, and democratic leadership can flourish. This is a much more desirable situation than exists in societies which continue to use the Comenian "printing minds" education system to either direct or even limit the opportunities for its citizens to learn. The paradigm of Ergonomic Education, in which the foundations of knowledge, skills of management, and engineering must be combined to build a post-Comenian educational system, appears to be a necessary condition for successful leadership of advanced democratic societies in the world.

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