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Our current society is seeing the impact of compounding vicious cycles of disparity, dividing our society between those that are well resourced and those that are not. This expanding disparity is not limited to wealth, but is also at play in education, employment, research (or being understood), digital access and influence. Although the democratizing potential of emerging socio-technical practices such as global networks could disrupt these cycles; the design of technologies such as search engine optimization, social media promotion, and Big Data analytics only amplify and speed the widening of the gap by creating echo-chambers of popularity and attention. This means that those with advantage and privilege gain more wealth and influence creating an ever-widening gap. This has dire consequences for society as a whole. [1]

One locus of intervention that has the greatest promise to address this critical dilemma is education. Investment in inclusive education and education about inclusion has a multiplying effect that can garner an impact that far exceeds the initial effort. However, to achieve inclusive education we must address a number of entangled factors. Chief among these are a) our systems of research, inquiry and evidence depended upon to expand knowledge and advance quality, and b) inclusive access to digital systems that have become integral tools of education.

Current Research Methods, Diversity and Complexity

Like our markets, our systems of research and evidence are systemically biased against diversity.[2] In our attempt to understand complexity and find dominant patterns, we elide the outliers.[3] This creates compounding disparities that ripple well beyond the topics of research. Our current systems of academic research leave a host of issues and individuals stranded at the edges: students who don't fit under the constraining mantle of average or the clusters of recognized classifications, patients whose unique condition means there is not a large enough representative research sample to reach statistical power to draw generalizable conclusions, or consumers whose unique needs will not warrant a product because the size of the customer base will not be profitable. Persons that do not fit into any representative sample are less likely to be represented by research or scholarship and are less understood, or worse, they are misunderstood and misrepresented. This has implications for policy, markets, systems of education, systems of employment, government services and all facets of life. Demographics show that these margins may collectively outnumber the "norm".[4] [5,6]However, our current systems of research funding perpetuate this pattern - leaving peerless research, research that cannot achieve statistical significance, subject matter without well-established disciplinary backing, and academic institutions that do not already pass high impact metrics without the needed support to sustain inquiry.

This dominant and pervasive pattern of formal research puts our society at risk of knowledge blind spots: hampered in predicting the occurrence of threats; unable to

adequately address the needs of all but the set of conforming groups; and, without the innovation and creativity birthed by addressing the edges.[7,8]

Perhaps more troubling than the gaps and disparities in research topics is the trend for "Big Data" systems, to replicate traditional diversity-and-complexity-aversive research methods. This accelerates the echo-chamber effect, emphasizes dominant patterns, and amplifies the bias toward what are deemed "high-impact" research issues. As reaching the bar of "high-impact" requires homogeneity in large numbers, individuals with outlying or minority needs can never reach the bar. Yet collectively these outlying needs may surpass - in urgency and volume - the needs that are deemed "high-impact."

As expressed by Brooke Foucault Welles[9], an unexploited opportunity provided by Big Data is that "those who might otherwise be represented as a single outlier in a more traditional dataset can number hundreds or thousands in a Big Data dataset—hundreds or thousands whose experiences are currently absent from the scientific record. Rather than actively removing these voices through sampling and data cleaning, or passively silencing them through statistical aggregation, … embrace the opportunity to examine the statistical outliers… By choosing to make Big Data small, we can rectify historical omissions and biases in social science research and build better, more comprehensive, bigger understandings of human behaviour."Small, thick data is personalized data in context, and practices that enable bottom-up data analysis. Rather than imposing the research parameters, relevant parameters emerge, data can be aggregated, and patterns are identified post hoc.

Sally Engle Merry in her book, *The Seductions of Quantification*[10] explores how global indicators are shaped by inequalities in power and expertise. She identifies a phenomenon called "expertise inertia." – "insiders with skills and experience have a greater say in developing measurement systems than those without—a pattern that excludes the inexperienced and powerless." Authoritative expert knowledge is given privilege, meaning that local knowledge is often ignored. The expense of collecting new data leads to an associated phenomenon Engle Merry calls "data inertia": "It is relatively hard to address new problems without new data collection, so the way categories are created and measured often depends on what data are available."

As scholars our research review, tenure, promotion, publishing, research recognition and funding processes are implicitly biased against minority needs. In the race toward impact metrics needed to be published, receive tenure, be promoted, receive recognition, and garner research funding; scholars are channeled toward research that can yield large sample sizes and homogenous outcomes that result in statistically significant findings. Reliance on peer review perpetuates dominant interests as researchers value research that strengthens their research domains. Disciplinary siloes mean that many topics fall through the cracks. Personal investment in demanding academic development often leads to competitive and elitist attitudes regarding what is worthy of inquiry. Each of these tendencies exacerbate the vicious cycles of disparity and run counter to the founding visions of scholarship.

At the same time as there is an echo-chamber of research topics within the formal research community -- that leaves outlying areas of inquiry ignored; tools and strategies are emerging that can put data gathering, processing, aggregation, analysis, visualization,

comparison, dissemination and replication in the hands of non-academic citizens and students in primary and secondary school. These technologies include: Internet of Things monitors and sensors (e.g., biometrics, environmental, smart home, etc.), personal mobile apps, complex data query systems invoked by natural language questions (e.g., "Siri, what is the current population of Nunavut?"), the adoption of open data practices by public institutions, and personalized data analysis tools (e.g., exercise guidance based on personal data). This enables a bottom-up emergence of citizen inquiry that has the potential to fill the gaps left by academic research. [11] Unfortunately most of these tools are not designed inclusively; excluding many of the very citizens excluded by formal research.[12] Many emerging tools and practices present barriers for individuals with disabilities that require alternative access, and individuals unfamiliar with highly technical terms or conventions. Citizens in rural and remote areas and citizens without the necessary financial resources to purchase new personal technologies are also frequently excluded.

Digital Exclusion or the Widening Technology Gap

Emerging educational technology has the potential to render accessible previously inaccessible curriculum and learning experiences and to democratize research to fill knowledge gaps.[13] However this potential cannot be realized unless we address the issues of digital exclusion. At the same time as there is an increase in the incidence of disabilities, there is a growing "technology gap" for individuals who have difficulty using or who cannot use standard computer systems. Access for individuals with physical, cognitive and sensory disabilities is currently dependent on specialized technologies called assistive technologies. These assistive technologies are relied upon to fill the gap between the user interface alternatives provided by the standard software and hardware and the alternative access needs of individuals with disabilities. Legislation and policy is constructed in such a way that the responsibility of the developer of standard ICT to provide equal access ends at the point where assistive technologies begin. The assistive technologies are the financial responsibility of the user with a disability or their support system and in many cases the public purse.[14]

The assistive technology industry, that bridges the gap to enable computer access, is a very tenuous and crisis-ridden industry without a viable business model. Most AT developers are small to medium enterprise companies. By virtue of the nature of their products, their customer base is limited. Given the heterogeneity of the needs of people with disabilities, the better the developer is at serving the needs of their customers the more limited this customer base becomes. At the same time they have an extremely challenging and unpredictable technical task. The products they create must interoperate with all software and hardware a computer user may wish to use. If this is not the case then individuals with disabilities will be limited to specific software applications e.g., able to only use a specific spreadsheet application.

The AT must accurately and reliably interpret the output of the computer so that the individual with a sensory or cognitive disability can perceive and understand it, and interpret the available voluntary actions of individuals with motor disabilities to accurately control and provide input to the functions of the computer. This requires a level of communication with the hardware and software that is frequently not built into the standard products. Many software and hardware systems are proprietary and their

developers closely guard information needed by the AT. This means that the AT developer must create work-around solutions or “hacks” that are frequently very brittle, failing when there are any changes to the standard system.

This situation is exacerbated by a number of ICT industry characteristics that are likely to become more prevalent. Every time a software application (whether a desktop or Web application) is upgraded the AT must also be upgraded. For even a moderate set of applications this can mean several upgrades a month. Another exacerbating factor is the now standard trend toward application “mashups”, increasingly the development of a given application cannot be attributed to a single developer but is put together and dynamically updated from multiple sources. In attempting to trace the provenance of a given application one can find that well over 30 companies have had a hand in developing components.[15]

Frequently ground gained in AT interoperability is eroded with the next wave of changes. HTML (Hypertext Markup Language), the primary language of the Web, by virtue of its structure, standard markup conventions and the inherent independence of the content and structure from the presentation or rendering was very AT “friendly.” With the emergence and increased prevalence of rich internet applications, and competing native mobile applications, which have resulted in a proliferation of non-standard interface conventions and markup, the domain of the Web and the many Web applications have also become a domain fraught with major interoperability challenges for AT.

Similarly as computing moves to mobile devices, means of interfacing, such as available ports for connecting alternative keyboards or displays are frequently reduced. The more disjointed the market and non-standard the system architecture or communication protocols the more difficult it is for AT developers.

All these factors contribute to a troubling trend for assistive technologies. While we can take for granted that standard ICT will continue to decrease in price, and increase in functionality, reliability and availability, the opposite is true for AT. Assistive technology is increasing in price and decreasing in functionality, reliability and availability.

This makes participation in the digital economy a difficult prospect for many individuals. If you happen to lose your sight and you are required to use a computer for work or education, in addition to the cost of the standard software and hardware, you must also purchase assistive technology that ranges from 1,500 dollars to 13,000 and must be upgraded at least once a year (unlike many standard upgrades, these are not free). You can count on at least twice as many crashes and bugs. You can also predict that there will be many software functions that are simply not available to you and functions you have come to rely upon may disappear with the next upgrade. This is added to the other barriers you must overcome on a daily basis.

This is if you live in a country that is in North America, Western Europe, Japan, Australia or New Zealand. If you live anywhere else, assistive technology will not be available in your country, will not be maintained or serviced in your country or if it is, it will likely cost more than 50% of your annual income. Consequently if the standard technology is not accessible to you then you will be excluded from all computer-mediated tasks. Given that most computer technology is designed for the market that has access to AT, standard computer technology will not be accessible to you.[16]

One potential means of addressing this technology gap is to shift the responsibility for addressing the needs of all end users to the standard technology developers. This will compel these developers to include alternative access features in their standard software and hardware (e.g., Apple has included screen reader functionality as a standard feature of its iPad, iPhone and iPod Touch technology making it directly accessible to individuals who are blind), or to engage assistive technology developers in filling the gap. This will potentially address both technical and business issues faced by the AT industry in that they will no longer rely on one of the poorest constituencies for revenue but on the ICT industry. It will also ensure that standard ICT developers will share information needed to create interoperable AT. AT development will be integrated into the standard ICT work processes.

The necessary legislative or policy reforms to effect this shift in responsibility is unlikely to occur if there is not as shift in the powerful and organized lobbying capacity of the ICT industry combined with fear by the AT industry that they will be made redundant by alternative access features in standard technologies.

The Theory of Inclusive Design

Inclusive design focuses on the edges or margins. Rather than designing for the typical, average or mass-population, inclusive design takes the perspective of individuals that: have difficulty using or cannot use the current design, or are experiencing a gap in available designs to achieve a goal. [17]

At the edge or at the margins there is far greater diversity. It can be said that the only common characteristic of disability, for example, is difference.[18] Because the dominant trend is to design for the average, typical or mass, this difference causes a mismatch between the needs of the individual that is different, and the design of the environment, product or service: which results in the experience of disability.[19] Our dominant designs similarly exclude other individuals in the minority, whether the difference is language, culture, gender, age, background or other aspects of human diversity. Anyone can find themselves at the edge and experiencing a mismatch.

Unlike other design approaches, inclusive design (as it has emerged and evolved in Canada designs “with” rather than “for.” The process of inclusive design grapples with the questions: “Who is not included?” “Who is not participating in making design decisions?” ”Who will be indirectly impacted by this design?” and creates an integrated approach that works hard to include these individuals as co-designers in the ideation, design decisions, evaluation and iterative improvement of a design. It has been shown that designing with people at the edges of a design domain stretches the design so that it becomes better for everyone and leads to greater innovation. This applies to the design of policies, processes, products, governance models, environments and products.

Inclusive design intentionally blurs the distinctions between the designer and user, the consumer and producer, the learner and the educator, the expert and the non-expert, the service provider and the client or customer. These distinctions reinforce constraining assumptions and ruts in thinking that perpetuate exclusion.

Focusing on the edges requires a systems approach. People at the edges or margins currently encounter many confounding systemic biases or barriers. The success of the

design is dependent on an awareness of the complex adaptive systems that make up the context of the design and the co-designers (users).

Inclusive design must grapple with two apparently conflicting criteria: to create designs that do not segregate (integrated designs), while also designing for diverse personal fit. This is achieved by designing flexible systems that are responsive to diverse personal requirements. This is most easily achieved in digitally mediated contexts as these contexts offer more mutability as well as the "connective tissue" to create a responsive system.

Inherent in diversity is both a challenge to the status quo and an opportunity to address current risks. Our current systems of design, research, representation and production do not support diversity. *Diversity increases complexity. Diversity also increases choices. The edges, where diversity is the highest, offer the greatest untapped potential.*

The margins of our society, which are currently systemically underserved and ignored, represent an extremely rich pool of skills, resources, resourcefulness, creativity, and motivation for change. One person's unmet need may be another person's skill or competency. [20]

Given the paucity of resources devoted to addressing inclusive design and the large diversity of individuals excluded by current designs, inclusive design is compelled to be collaborative, open and transparent, rather than competitive and protective. The challenge is too great to invest in redundancy and barriers to sharing. (Rather than a scarcity of demand there is a scarcity of supply and a scarcity of tools, knowledge and resources to meet the diverse, fragmented, disbursed demand.)

Emerging socio-technical innovations offer the opportunity to orchestrate a system that realizes this potential at the edges. Current barriers for systems, services and markets that serve the margins include: fragmentation of consumer base, poorly articulated requirements, badly understood quality criteria, lack of feedback and prioritization, lack of resources and tools, and lack of integration.[21] In fact these systems, services, research efforts and markets face the same systemic biases encountered by the individuals they intend to serve.

Global networks or sharing economies have emerged for many other previously fragmented markets (e.g., ridesharing, tool libraries, sharing homes).[22] An open networked platform and inclusively designed socio-technical ecosystem that matches unmet demand with potential responses, pools and shares tools, services, resources, training and knowledge, and provides feedback data, may address barriers for consumers and suppliers or service providers at the edges.

Applying Inclusive Design to Education

Our systems of education globally can be characterized as complex adaptive systems within the larger complex adaptive systems of our society. [23] Formal education systems were built to resist change (and pressures from political forces or transient ideologies), but are caught in inevitable and unprecedented disruptive technical, economic and social changes. Education disparity, and barriers to learning can be seen as wicked problems, or problems that are "difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize." [24] Successful

interventions in these systems cannot be simple or static but must be responsive and adaptive: taking advantage of movement that provides opportunities for the desired outcome of inclusive education, and adjusting course when new challenges arise.

The combination of: the move to digitally mediated education, adoption of Open Education Resources (OER, openly licensed curriculum and textbooks) and open education, explorations in personalization, personalized data analytics, and connected communities and classrooms – offers a convergence of factors that can be catalyzed to remove barriers to education for students who are marginalized. [25] However, with opportunities also come challenges including reactionary promotion of exclusive education, and interpretations of quality that are needlessly reductionist.

All learners potentially face barriers to learning. These barriers are a product of a mismatch between the needs of the learner and the learning experience and environment. Learning needs that affect learning can include:

- sensory, motor, cognitive, emotional and social constraints,
- individual learning styles and approaches,
- linguistic or cultural preferences,
- technical, financial or environmental constraints. [26]

Like economic disparity, education disparity is intensified by complex factors that reinforce inequity and disadvantage for excluded learners. In addition to the barriers listed above learners often face attitudinal and economic barriers as well.

Most formal education systems do not currently recognize that all learners learn differently (or that our transforming society requires a diversification of learning outcomes). [27]However, as an increasing number of students disengage from learning at a time when education is more important than it has ever been, there is a nascent responsive movement toward personalizing education. This move toward personalized learning offers an opportunity to support previously marginalized learners, if the concept of personalization is broadened to encompass a greater diversity of learner needs.[28] This intervention to broaden the understanding of personalized learning must happen before conventions are set and the larger course toward personalization is determined.

To align personalization with accessibility policy requires an understanding of disability as a mismatch between the needs of the learner and the education experience offered, and an accessible learning experience as a learning experience that matches the needs of each individual learner. Thus a resource cannot be labeled as accessible or inaccessible until we know the context and the learner/s. This aligns well with OER best practices, learning outcomes research including deeper learning theory, Universal Design for Learning, differentiated learning and evidence regarding good pedagogy in OER-based education. This framing merely adds an additional critical impetus to the broader goals and values of the open education community. The added push recognizes that some learners are more constrained than others and are therefore less able to adapt to the learning experience or environment offered, with the result that the learning environment or experience must be more flexible.

The emerging open education ecosystem, if designed inclusively, can provide promising interventions in this complex adaptive education system and attenuate the wicked problem of education disparity, reversing vicious cycles of exclusion. By virtue of OER diversity, and openness to revision, remixing, and personalization, an education program based on OER and open education can address the highly variable needs of currently excluded or disadvantaged learners. Disability and poverty are often co-occurring, with a disproportionate number of people with disabilities well below the poverty line globally. It can cost as much as ten times or more for someone with a disability to get online and use a computer through required alternative access systems. Thus the cost reduction brought about by OER has a large impact on students with disabilities as well. By democratizing the production of curriculum, OER systems are also more open to designing for diversity and supporting diverse teacher needs.

The FLOE Project is a project funded by *The William and Flora Hewlett Foundation* to infuse accessibility into the open education ecosystem. [29] The core challenge addressed by the FLOE project is to design the OER ecosystem to address the full diversity of learners and thereby improve the learning experience for all learners (See Figure 1). As inclusive design of learning constitutes a change in a change-resistant education system, practitioners of inclusive design within education -- whether teachers, administrators, schools, or school authorities -- face resistance and mismatch as well. Any intervention into this wicked problem requires that all stakeholders are taken into account and supported in making the necessary changes.

Ideally, learning is a continuous and iterative process of designing a fulfilling life. A framework developed by the author and applied by the Inclusive Design Research Centre called “the three dimensions of inclusive design” recognizes that inclusive design in a digitally transformed and connected society can be relative to the individual, the goal and the context.[30] The same framework is used by the FLOE Project as a notional scaffold for inclusive learning.

The first dimension is the understanding that full inclusion requires the recognition of **individual difference** and uniqueness; that design, and learning must be individualized; that individual requirements vary given the context and the goal; and that inclusion requires personal agency by fostering the self-knowledge of each learner. Adaptations to individual needs must be integrated, not segregated, to remain sustainable and current. Choices must vest with the learner, and any intelligence gained about the learner must be shared with the learner to support meta-cognition and self-guidance.

The second dimension is an **inclusive process** of design or learning design. This ensures that the learner is an active participant in the full design cycle through co-design. The design, development or instructional tools used must be accessible to the full diversity of co-designers. The design team should consist of a diversity of perspectives. This would mean that learners co-create with diverse peers and experts and that all learners not only consume curriculum but also produce curriculum.

The third dimension recognizes the **larger context**: the complexity and interconnectivity of phenomena and systems. The design and learning process must take into account the greater impact of any design and strive to effect positive systemic change and at

minimum do no harm to linked systems. Here the learner recognizes their unique, evolving role and impact within the complex and evolving global community.

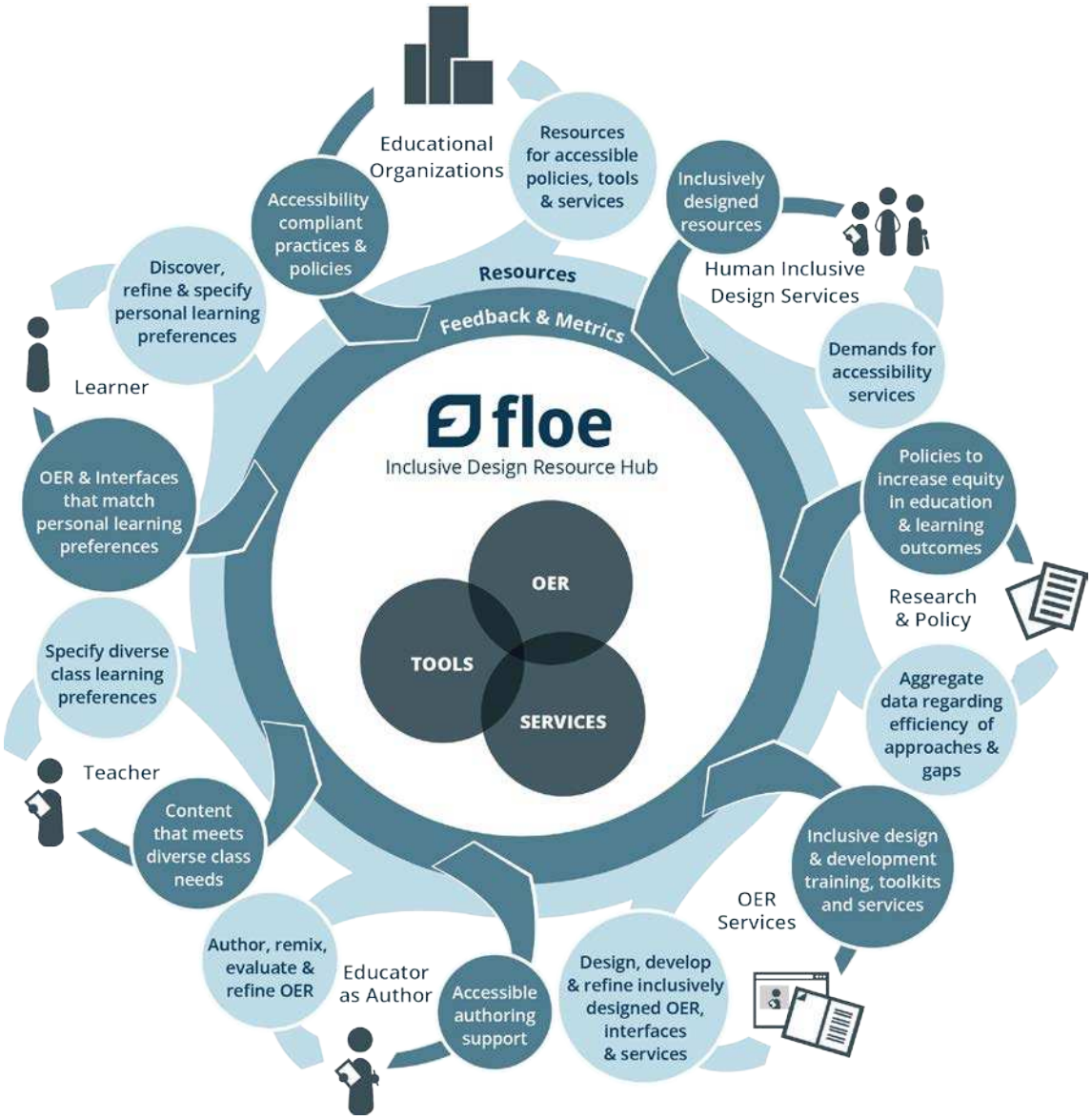

Figure 1: The FLOE Project Open Education Ecosystem

Online communities, supported by platforms, that match unmet demands with responsive supply and integrate feedback loops to inform continuous improvement and guide adaptation, appear to be the most promising means of productively intervening in the complex adaptive systems of our quickly changing connected society.[31] These communities require participation from the greatest diversity of participants in the full range of roles as possible, and a critical mass of participation from both the demand and supply side. The move to inclusive design for learning (including inclusive design, Universal Design for Learning, and differentiated learning) has reached a maturity level and acceptance or demand level that can sustain this critical mass.

Wicked problems can only be solved through collaboration and agile trial and error. [32] By creating a community platform for an ecosystem that: enables organic growth and extensibility, welcomes a range of stakeholders and holds itself to the same inclusive design standards as it supports; the FLOE Project improves the chances of successfully untangling the wicked problem of education disparity and catalyzing greater inclusion. An open and transparent effort with continuous recruitment of further collaborators has the potential to allow the impact to organically grow from small successes. Transferring ownership and authorship of the resulting resources to the greater open education community as quickly as possible helps to speed adoption, integration and fit for purpose. The momentum and participation of dozens of education efforts globally in the FLOE effort can be seen as attestation to the success of this strategy.

Conclusion

There is a growing global understanding of the importance of inclusion in the advancement and survival of civilization.[33] Diversification supports responsive resiliency, whether in economics, biospheres or social systems. Exposure to difference and the extension of empathy (expressed through inclusion) is the social glue that allows greater responsive complexity, innovation and flexibility needed to address increasingly confounding systemic threats and to realize redemptive opportunities.[34] Inclusive education has a critical role to play in turning around vicious cycles of disparity and realizing the potential of human diversity.

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