Education on the Shaky Ground of Humanism:
Space, Subject, and Digitalization

By

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ABSTRACT

The last two decades has seen a growing dedication to the digitalization of education, with numerous reports and classroom innovations arising and traveling across national lines. Much contemporary research on digitalization, however, identifies the same kind of problems that were raised twenty years ago: the careless migration to new technology without sufficient consideration of the contextual needs, a technification that prevents stakeholders other than technicians from accessing machinic mechanisms, and “restrictive institutional practices and short-sighted policy planning” as the outcome of politics among different interest groups and new information infrastructures. The dominant explanations for the persistence of such problems have been pedagogical, technological, and economic, rather than ontological. This dissertation questions and explores the ontological impacts of digitalization. It mobilizes Michel Foucault’s genealogy of the subject and Sylvia Wynter’s analytics of Man to understand how the philosophical bearings of the humanist subject, “Man,” and Newtonian, container-like theories of space operate as cornerstones of “modern” education that digitalization now challenges. The analysis further identifies how particular philosophical assumptions and concomitant digitalization processes made possible an educational subfield called STEM education. U.S.-based STEM education, as one of the outgrowths of digitalization, did not necessarily remain within the geopolitical territory that produced it. The dissertation thus examines the case of a high-profile STEM-oriented school in China, tracing traveling discourses that have moved between the U.S. and China, illustrating how the making of the subject occurs through an “othering” perception. Last, the analysis recognizes the more recent moves from digitalization to post-digitalization, demonstrating new possibilities of subjectivation by mobilizing Deleuze’s theory of “subject-space.” The implications for the discipline and practice of education are considered, including the specific fields of curriculum studies and educational technology.

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1. Education in an Awkward Position:

When the Making of Man Encounters the Making of Digits

> Something about it stirred a vague memory in her, but she couldn't recall what it was. She asked the ship what it was, via her neural lace.
>
> ~ That is a neural lace, it informed her.
>
> ~ A more exquisite and economical method of torturing creatures such as yourself has yet to be invented.
>
> IAIN M. BANKS, *Excession*

1.1 INTRODUCTION

The neural lace, a wireless brain-computer interface implanted in the brain of the futurist post-humans in Banks' novels, *The Culture series*, programs the neurons to release certain chemicals so that a thought can occur like it occurs "naturally" through the biochemical mechanism. The neural lace grows not only into but also around the brains, like a souped-up Wi-Fi, forming networks of "minds" under the control of a super artificial intelligence. From running "online" communication and communing, to waking up its users by pumping adrenaline, and to handling their orgasm sequences, the neural lace eradicates the boundaries between public activities, daily routines, and intimate interactions by turning its users inside out, constructing a flattened-up space where nothing has an "interior," and reframing the "self" as flows of information perpetually awaiting calculation and inspection: “A more exquisite and economical method of torturing creatures such as your-*self* has yet to be invented.”

The neural lace is more than a wild imagination confined to science fiction: 2020 witnessed one of its most updated prototypes, the Neuralink, becoming a reality. The Neuralink is a brain computer interface which allows for a two-way communication between the brain and the computer: “For example, through information readout from the brain, a person with paralysis can control a computer mouse or keyboard. Or, information can be written back into the brain, for example to restore the sense of touch” (Neuralink, 2021). Having its “sensory organs,” the micron-scale threads containing electrodes that detect and record neural signals, and a chip called the “link,” which “processes, stimulates and transmits neural signals,” installed into specific areas of the brain, the Neuralink visualizes and simulates “thoughts” through a digitalized operating system, as if electrodes, chips, screens, together with codes, algorithms and databases could anatomize the “mind” like scissors and knives once dissected the body. The project team developing the Neuralink expect to “expand our world” and “eventually to expand how we interact with each other, with the world, and with ourselves” (Neuralink, 2021), meaning they are clearly aware of where such an invention has been orienting towards: the erosion of the frontiers of the “modern” space *along with* the paradigm shift of the Self, or the subject.

Indeed, our world is “expanding,” as the tentacles of information start to (re)colonize any underexplored “depth,” and as Self-Other interactions are “expanding.” Every being (the Self and the Others alike) is fragmented into binary digits (bits) for “storage, circulation, reference, and classification…according to the objective that is being sought” (Foucault, 1997, p. 331). A sociotechnical process called digitalization is remapping the contours of “space” and “subject,” disturbing not only the mundaneness of everyday life, seen in the saturation of electronic media and the internet[1], but also the infrastructure of well-established disciplines and professions. Stevens (2013), for example, describes how biology is attending more to "problems computers can readily solve" (p. 21), when organisms are viewed as algorithms, than to "wet" laboratory discoveries. Here the mutual formation of the biological subject (what is doing "biology"?) and biological sites (where is "biology" happening?) plays a pivotal role in shaping the landscape of informatized biology, or "bioinformatics."

Education counts on subject and space like biology does, if not more so, since it is "the fundamental and most significant system of subjectification in society" (Knox, 2016, p. 318) and since it is "dominated by the spatial"[2] (Sheail, 2015, p. 37). In a context where students have been increasingly immersed in the digitalized lifeworld outside the school and where on-campus digitalization has become a "new" reality since the 1990s[3] (and a necessity since the outbreak of the COVID-19 pandemic), it is important to revisit education, to revisit its sustained structural problems, from the "subject-space" perspective.

1.1.1 Research Questions

This work is an attempt to understand how education, when digitalized, responds to the co-evolution of subject and space. It asks the following research questions:

1. What issues and problems regarding digitalization have been raised in the contemporary discipline and practices of education? In chapter 1, I examine the main concerns raised in current literature around the "digital divide" and "digital use divide," the prejudice built in the digital black box, and the marketization featured with grass-roots users' voluntary contribution and self-responsibilization.

2. Drawing on Foucault and Wynter's understandings of Man, how can issues and problems regarding digitalization be understood in relation to conceptions of the "subject" and "space" that found "modern" education? In chapter 1, I interpret such issues and problems as forging a reconfiguration in existing theories of the subject and space that underlie "modern" education. In chapter 2, I attribute the unfulfilled promises of U.S. STEM education to improve "human" conditions to problematic assumptions relating to "human" and "space."
3. How do particular philosophical traditions, discourses, and trends in digitalization enable the formation and practice of STEM (science, technology, engineering, mathematics) education in the U.S.? In chapter 2, I explore a particular set of philosophical traditions (philosophies of science by Descartes and Kant) through Foucault's historiography and an educational discourse of "dystopia" through Foucault's analytical tool "statement." In chapter 3, I review trends in digitalization, without which science and STEM education could not possibly become what they are at present. I bring together these strands, seeing them as conditions of possibility for the neologism "STEM education."
4. How can Deleuze's theory of subjectivation help address the persisting and emerging problems in the digitalization of education, in particular, in a STEM-focused high school in Hangzhou? In chapter 3, I explicate Deleuze's tripartite narratives of space, time, and subject and show their potentialities to disrupt the established canon of subject-making and space-imaging through a specific case study that traces the movement of STEM discourses between the U.S. and China.
5. What are some broader implications for education on the shaky ground of humanism? In chapter 4, I map out the significance of this work as a move "beyond" or "post" digital,

enumerate its contributions and limitations, and propose to make future research more contextualized and more open.

To be clear, this work does not debate whether education should embrace digitalization, for digitalization is not an option. Nor does it examine how to contextualize certain digital techniques for particular educational ends, for enormous efforts have been and are made to improve the efficacy and efficiency of educational technologies in general and on a case-by-case basis. This work advocates exercising prudence in epochal changes in and through digitalization, since "if it is a certainty, then it is not a turning point. The fact of being part of the moment in which an epochal change (if there is one) comes about also takes hold of the certain knowledge that would wish to determine this change, making certainty as inappropriate as uncertainty" (Blanchot, as cited in Stiegler, 1998, p. 1). Here it "takes hold" of the knowledge of "subject", "space" and "digitalization", steps back from the prompt action on digitalization within the existing frame of modern education, and delineates uncertainties, challenges, and possibilities that might even rename what is currently called "education."

This work is informed by three lines of reasoning: First, Foucault's historiography of subjectivation and his analytical tool "statement." Foucault's historiography of subjectivation illustrates that the currently predominant humanist subject, Man, is but the effect of a particular European tradition of self-mastery, and his analytical tool "statement" illuminates the regularity that organizes objects, concepts, or thematic choices, and so forth. Second, Wynter's profiling of the secularization of humanism, which defines as fundamental to global injustices and violence the overrepresentation of Man for human. And third, Deleuze's theory of subjectivation, which offers "self-on-self" techniques other than that making Man. I elaborate on these three lines of reasoning in the theoretical framework section below.

First, however, in chapter 1, I examine Research Question 1, laying out the issues and problems in regard to digitalization in contemporary educational research and practice. Second, I lay out my theoretical framework and its three strands, responding to Research Question 2 with an explanation of how the path, end, and troublemaker of modern education as a transcendental, "rational" subject called Man has been linked to a particular paradigm of space. Here through Foucault's historiography of the "subject" and Wynter's notion of Man, I examine pre-existing "Western" orientations to both Man and the space linked to Man to make clear the linkage that has occurred in/as education and the problem that digitalization now poses in regard to this linkage. Through Deleuze's theory of "subject-space," I also explore a way of theorizing and practicing "subject-space" for education to survive the digital upheavals and I check the relationship this way has to groups currently identified in education as "marginalized", "underrepresented", and "Othered". In the final section, I offer an outline of chapters to come.

1.1.2 Key Terms of the Study

Before moving through these layers, and especially because terms of classification such as "marginalized," "Western," "modern," and so forth, are so fraught in the educational field, I want to specify some caveats around the use of key terms in this dissertation. To put it concisely, these terms are used as the groundless ground, which, paradoxically, has to be de-solidified or suspended for the current research to land on. On the one hand, as the basic "code" of educational discourses, these terms constitute a "ground" that this research is not able to skip over. For instance, chapter 2 and 3 demonstrate how the term "marginalized," together with other terms it overarches ("black," "disabled," "women," etc.), permeate educational discourses which helped make possible "STEM education" in the U.S. Indeed, such terms are essential to educational policy and everyday practice, and are *real* both as word and world, in that they define similarities, differences, and identities which account for people's real-life experience and suffering.

On the other hand, though this research must land on the "ground" constructed by these terms, it does so by de-solidifying or suspending the "ground" first. Terms that cut the world into the "marginalized" and the "mainstream," the "West" and the "Rest," the "modern" and the "yet-to-be-modernized," are made "groundless" through the genealogy of Man, which over-represents itself as human and serves as the "grid of identities, similitudes, analogies," according to which "we become accustomed to sort out so many different and similar things" (Foucault, 1989, p. xxi). In other words, this research sees the taken-for-granted classifications at present as non-essentialist, non-dualist, and in constant de/re-territorialization, as exemplified by chapter 2 and 3's discussion on the conceptualization of "STEM education" through multiple conditions of possibility and travelling discourses.

Terms expressed in the title, i.e., "education," "the shaky ground of humanism," "subject," "space," and "digitalization," underlie the whole dissertation and will be elaborated in the text. But a brief introduction of them is provided here to facilitate further explication.

"Education": To give "education" a definite meaning is both arrogant and impracticable. In this work "education" refers to a "modern" discipline and practice that got established out of several historical traces, including an age of intellectual inquiry ushered by the Renaissance, the predominance of the printing press marked by the Gutenberg Revolution, the orientation to secular and economic needs posed by the Enlightenment and the Industrial Revolution, and so forth. Such a conception of "education" is getting through constant change, and this work demonstrates how it is being remapped through a movement called "digitalization."

"The shaky ground of humanism": "Humanism" is related to heterogenous discourses such as those advocating values related to classical literature, those signifying a secular attitude towards life, those highlighting the rights and responsibilities based on the autonomy of "human beings," etc. This dissertation takes "humanism" as a historical movement in which "a strange figure of knowledge called man" became inherently capable of truth (capable of accessing truth without changing its ontological status) and "revealed a space proper to the human sciences" (Foucault, 1989, p. xxvi). "The shaky ground of humanism" refers to the destabilization of such "a strange figure of knowledge called man" when the making of digits turns into a way of knowing and being, as Foucault mentions: "Man is only a recent invention, a figure not yet two centuries old, a new wrinkle in our knowledge, and he will disappear again as soon as that knowledge has discovered a new form" (p. xxv).

"Subject": The "subject" can be traced back to Aristotle's two main constituents of a clause, one is the "subject," about which the argument is made, and the other is the "predicate," which makes argument about the "subject." Arising from the metaphysics of language—the "subject-predicate-object" structure—are the dichotomy of the "subject" and "object," as well as the "will" or "agency" of the "subject." This work takes a Deleuzian perspective on the "subject," seeing it not as a "cause" but as an effect of the "predicate": "A subject is defined by the movement through which it is developed" (Deleuze, 1991, pp. 85).

"Space": This dissertation endeavors to deconstruct the conception of "space" as a receptacle or container on which movements of things occur. It sees space not as an *a priori*, but as co-produced with time and "things" by movements. In his work *Bergsonism* (1966/2011), Delueze distinguished two types of space: one is the false space (the container-like space), which is "a fiction separating us from psychological reality," and the other is the real space, which is "itself grounded in being" (p.34). "Time" is also an important concept which is always conjoined with "space" in some philosophies, e.g., in Deleuze's theory of subject-making, the subject appears "in three series: Space, time, and also consciousness" (Deleuze, 1994, p. 220). While this writing gives special attention to "space" because the computer produces "Space, time, and also consciousness" through spatialization: the computer turns "individuals" into "'dividuals' …masses, samples, data, markets, or 'banks'" (Deleuze, 1992, p.5) and operates by sorting these "dividuals" spatially.

"Digitalization": There is a careful distinction between "digitization" and "digitalization" in computer science and information technology. Digitization is a "technical process" of "converting analog signals into a digital form, and ultimately into binary digits (bits)," while "digitalization" refers to the "sociotechnical process of applying digitizing techniques to broader social and institutional contexts that render digital technologies infrastructural" (Tilson, Lyytinen and Sørensen, 2010, p. 749). Economy is amongst the "social and institutional contexts" that have been most thoroughly revolutionized by digitalization, as goods made of bits are reproduced at nearly zero cost and transmitted almost instantaneously across the world (Brynjolfsson and McAfee, 2016). And in economy, digitalization is defined as encoding information into a stream of bits, "Digitization, in other words, is the work of turning all kinds of information and media—text, sounds, photos, video, data from instruments and sensors, and so on—into the ones and zeroes that are the native language of computers and their kin" (p. 61). Another term related to "digitalization" is "postdigitalization", which indicates the condition under which digitalization is not over but has progressed from a distinct outbreak (the digital revolution) to an ongoing condition. In other words, "postdigitalization" addresses the state where the digital technology is so ingrained in the infrastructure of social contexts that it disappears from the everyday vision and consciousness through it plays a vital role in shaping daily lives.

1.2 LITERTURE REVIEW: MODERN EDUCATION SITUATED IN DIGITALIZATION

> Vast Resources have been invested in technology-enhanced learning and instruction. Many people have faith that technology will make education better. Such faith is ill-founded.
>
> J. MICHAEL SPECTOR, *An Overview of Progress and Problems in Educational Technology*

Two decades ago, Spector (2001) suggested that history tells a story different from the speculation that "dramatic improvements in learning and instruction…will be realized through innovative applications of new technologies" (p. 27). For example, the 1980s' expectation that intelligent tutoring systems would improve learning in ways similar to that of "some one-to-one human tutoring" (p. 27) did not come true, neither did the 1990s' prediction that "distributed learning and tele-collaboration would make classroom teaching and teachers obsolete" (p. 28). The main reason, according to Spector, lies in the difficulty of translating technology into contextually meaningful educational practices: "While it is true that technology has been a centerpiece in many instructional systems and learning environments, technology is not what learning is about … learning is essentially about change" (p. 30).

Such a recognition fuels, rather than diminishes, the enthusiasm for experimenting with up-to-date technology across a variety of educational settings, and at the beginning of this century, "these promises of technology-transformed learning and instruction exist[ed] … in conjunction with networked learning environments and highly interactive multimedia" that were made "widely accessible and affordable" (p. 28) by the advent and dominance of the internet and personal portable digital products[4]. "A Roadmap for Educational Technology," a 2010 report funded by the

National Science Foundation (NSF), fully appreciates the fact that current societies operate through digitalization and reconfigures the landscape of modern education by articulating "a comprehensive vision of educational technology toward 2030:" "We encourage dialogue that underlines the importance of education in an information society, and the changing nature of basic education" (the Computing Research Association, p. 4). The following graph taken from the report designates the potentialities of computing technologies to address existing challenges in education and to realize more educational possibilities within a 20-year span.

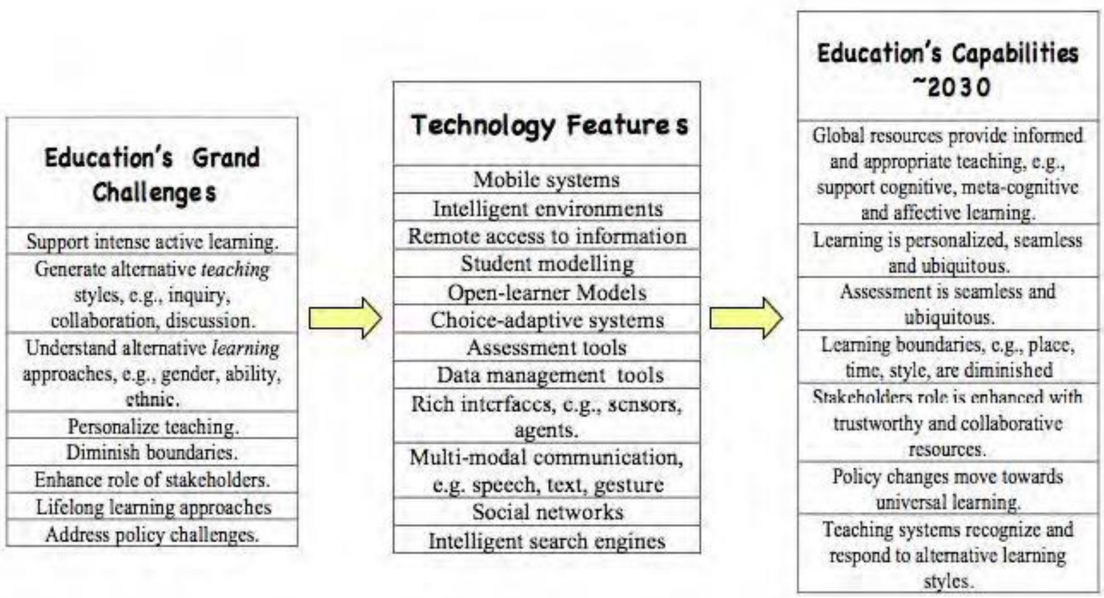

Fig. 8 "Challenges, Technology, and Future Educational Capabilities" (p. 14)

The launch of the above initiatives is but one early indicator of the blossoming of digitally mediated educational practices in the coming years. The 2010, 2014 and 2020 updates of the Federal Communications Commission's (FCC's) E-rate program, which provides discounts for internet connection to eligible schools and libraries, are prompt responses to the fundamental shift in education, "But learning is changing," through the "ongoing proliferation of digital learning technologies" and the "heightened reliance on remote learning during the COVID-19 pandemic" (FCC, 2020). And as a result, "When E-rate was established in 1996, only 14 percent of the nation's K-12 classrooms had access to the internet. Today, virtually all schools and libraries have internet access" (FCC, 2020). Moreover, from 2015 onward, the digitalizing transition of the National Assessment of Educational Progress (NAEP), which is also known as the Nation's Report Card and serves as the "common 'yardstick' in large-scale assessment," (National Center for Education Statistics (NCES), 2020) has exhibited institutional efforts to adjust the "legitimate" knowledge associated with paper and pen to that with computer: The assessment not only uses different interfaces, question types and tasks but also reports on "student actions on the assessment related to performance, such as those recorded through the keyboard and mouse" (NCES, 2020). Ensuring that "today's students are digital natives" (NCES, 2020) is more a legitimate agenda that has mobilized, is mobilizing, and will mobilize groundbreaking educational trends. Such trends may deploy technologies such as blockchain, augmented/virtual reality, social robotics, artificial intelligence, and so on.

Among these surging waves, where are we now? The latest[5] education policies and policy reports illuminate where modern education sees itself at present. For example, "The National Education Technology Plan" (NETP) (Office of Educational Technology, 2017), the "flagship educational technology policy document for the United States," has shifted its attention from the "digital divide" to the "digital use divide," which refers to the gap between "learners who are using technology in active, creative ways to support their learning and those who predominantly use technology for passive content consumption" (p. 7). The document names key goals such as "digital problem solver," "responsible digital citizens," "digital explorer," "digital literacy," "digital credentials and badges," "digitally enhanced curriculum," and so on.

Outside the U.S., to provide advice and support to European Union education policy, the Joint Research Center (JRC) of the European Commission has carried out research on “learning and skills for the digital era” since 2005. Its 2016-2017 achievement is a mapping of digital competence frameworks for “citizens and learners (micro),” “teachers and educators (professionals),” “educational organizations (meso),” and “societies (macro)” (JRC, 2016). Thus, the JRC has set conceptual foundations for its later series of forward-looking papers on the digital transformation of education in Europe. This series consists of three reports: First, “The Impact of Artificial Intelligence on Learning, Teaching, and Education: Policies for the Future” (Marcelino, etc., 2018), which underscores the “technical, social, scientific and conceptual limits” (p. 3) of the current AI systems and the ethical implications related to training AI to learn algorithms with historical data; Second, “Makerspaces for Education and Training – Exploring Future Implications for Europe” (Riina, etc., 2019), which addresses European Key Competences for Lifelong Learning by describing the characteristics of “makerspaces” where “tools, people, projects and expertise” gather and where interdisciplinary learning, real-world problem-solving, and flexible learning arrangements occur naturally. Thirdly, “Emerging Technologies and the teaching Profession: Ethical and pedagogical considerations based on near-future scenarios” (Riina, etc., 2020), which discusses benefits, risks and existing practices relating to integrating “trendy” technologies like social robotics, virtual/augmented reality, and wearable equipment to tackle educational problems as “old” as special education or as “new” as cyberbullying. The United Nations, considering its global perspective, nevertheless expresses its major concern over the “digital divide,” that is, the unequal access to the internet and devices, which is always overshadowed by other problems in U.S. and EU discourses. The document “Policy Brief: Education during COVID-19 and Beyond” (United Nations, 2020) warns that currently the most vulnerable groups are “those who have poor digital skills and the least access to the hardware and connectivity" (p. 8). Though the U.N. has been "engaging actively to support national COVID-19 education responses" by mobilizing a coalition of its own agencies, "international organizations, private sector entities and civil society representatives" (p. 19), it is mindful of the potential dangers inherent in the operation of capital, the driving force of digitalization: "Quality education cannot be provided through content built outside of the pedagogical space and outside of human relationships between teachers and students. Nor can education be dependent on digital platforms controlled by private companies" (p. 68).

So far, the map is clear. Like it or not, modern education is and will be going through digital reformation, for the conversation has shifted from situating digitalization in education to situating education in digitalization, as one interesting comment illustrates, "AI is now often called 'the next electricity'" (Marcelino, etc., 2018, p. 2). Still, digitalization is not necessarily making education "better" if structural inequalities are kept, transformed, or invented by the mechanisms inherent to digitalization. For example, feeding AI systems with historical data that "reflect cultural biases and historical salient measures" would lead to their treating "the world as a repetition of the past" (p. 4).

Concisely, the key problems in situating education in digitalization are a) the digital divide and the digital use divide; b) the prejudice built into the digital black box; and c) The marketization featured with the grass-roots users" voluntary contribution and self-responsibilization. The following paragraphs will further exemplify these problems in context.

1.2.1 Problems Brought to the Fore in the Digitalization of Education

a) The digital divide and the digital use divide

According to the United Nations International Children's Emergency Fund (UNICEF), the school closures under the influence of the COVID-19 pandemic has affected nearly 91% of the world's enrolled students, as of April 24, 2020 (2020, p. 1). One hard lesson from the COVID-19 education responses is that there is an "uneven distribution of the technology needed to facilitate remote learning" (p. 1). Specifically, the "electricity and connectivity infrastructure" and the "digital and media resources based on the curriculum," have prevented educational systems from implementing "Plan B" "in times of shock when core delivery models are disrupted" (p. 6). The following graph (Figure 9) demonstrates how household access to internet varies geographically:

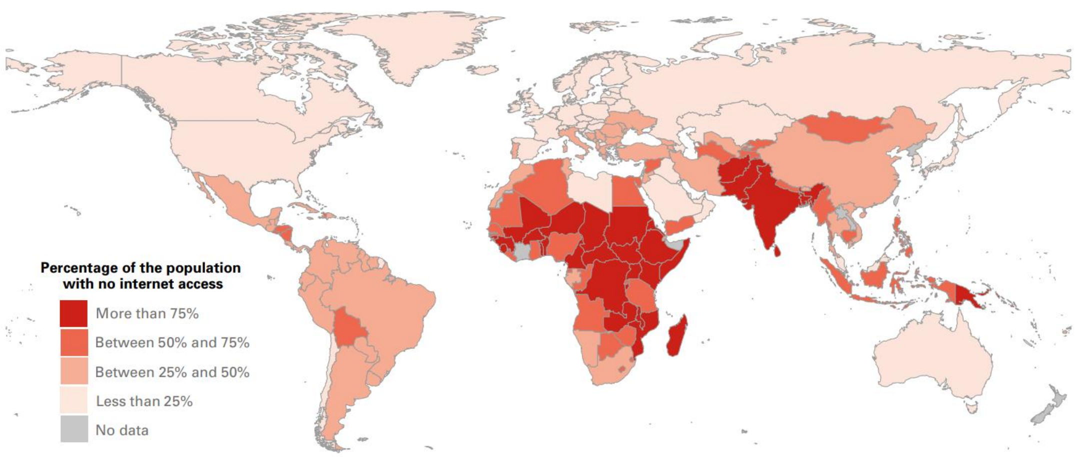

Fig. 9 "The Digital Divide: Percentage of population with no internet access"

"Source: ITU, Datareportal.com (latest data from 183 countries, 2015-2019)" (p. 2)

The report reads, "While internet use is widespread in everyday life and work for many in high income countries, this is not the case in most low- and middle-income countries. In 71 countries (out of 183 with data), less than half the population has access to the internet" (p. 2). What remains unsaid is more compelling: When the high-income countries turn their own territories into hyper-connected cyberspace, they are changing and making rules accordingly for the whole world. All societies, regardless of their connectivity, are included in this digital ecosystem; disadvantaged groups are assimilated by the least favorable means so that they, ironically, share the risks of the cyberspace. For example, a fluctuation of numbers on the computer screen at the London Stock Exchange could deprive a sugarcane plantation worker in the Philippines of his job. At the same time, that worker would not necessarily enjoy the possible benefits of this hyper-connected cyberspace, like taking advantage of resilient education systems supported by sufficient digital resources.

Therefore, investments in digital infrastructures, though essential, touch only the tip of the iceberg of structural inequalities. Studies have shown that closing the digital divide could even aggravate the digital use divide and structural inequalities if digital technologies are not thoughtfully contextualized (Attewell, 2001; Warschauer, 2003; Valadez & Durán, 2007; Warschauer & Matuchniak, 2010; Harris, Straker & Pollock, 2017; Mertala, 2019). For example, Mertala (2019) investigates the paradoxes in the master narratives of "Ed-Tech speak," which champions the "progressiveness" of educational technologies, and the polyphony of everyday praxis within the theme of participation. The research site was "an educational tablet project conducted in primary and secondary schools in the Finnish city of Kaarina" (p. 179) from 2014 to 2016, and the findings are as follows (see Table 1):

Types of Paradox	Master Narratives	Local Practices
Societal participation	Access enhances equity	Shift to tablet widened the gap
Participatory pedagogies	Mimics of informal digital lifeworld increase participation	Mimics were alienating
Politics of participation	Polyphonic discourses are valued	The “force feeding of digital”

Table 1. Paradox Between Master Narratives and Local Practices of the Kaarina Tablet Project

Mertala elucidates the three types of tensions via narrative analysis. The substitution of low-quality e-materials for printed books favored “the families with economic resources, [which] were able to tutor their children by providing additional learning resources” (p. 184). Thus, the less-privileged students and parents were rendered more vulnerable. Moreover, the school activities meant to imitate students’ “informal digital lifeworld” (p. 184) are “often merely superficial attempts with no sincere effort to understand what digital cultures and practices mean for students,” thus failing to engage students in teaching and learning. Finally, the top-down requirements of digitalizing education usually draw on powerful agents like the government for justification and are “inherently political, value-laden, and deterministic” (p. 179), leaving little room for teachers, students, and parents to advocate for themselves. In sum, the mission to replace printed books with tablets and transplanting acquisition methods from informal digital settings to schools interweaves various assemblages of histories, such as histories of pixels, screens, and semi-transistors, and those of ink, papers, and printers. Without this knowledge, efforts to close the digital (use) divide would turn, at best, futile, and, at worse, detrimental.

b) The prejudice built into the digital black box

> Like Gods, these mathematical models were opaque, their workings invisible to all but the highest priests in their domain: mathematicians and computer scientists. Their verdicts, even when wrong or harmful, were beyond dispute or appeal. And they tend to punish the poor and the oppressed in our society, while making the rich richer.
>
> CATHY O'NEIL, *Weapons of Math Destruction*

Mathematician O'Neil (2017) keenly senses the updates of mathematics occurring through digitalization: Mathematics now attends to "petabytes of information" primarily "scraped from social media or e-commerce websites" 24/7 and specializes in calculating and predicting human types: "Mathematicians and statisticians were studying our desires, movements, and spending power. They were predicting our trustworthiness and calculating our potential as students, workers, lovers, criminals" (p. ii). Mathematics, the core of the "hard sciences," is believed to yield algorithms with the power of surpassing the human fallibility. O'Neil points out this power is not true, though. She takes IMPACT, Washington DC's public-school evaluation and performance management system, as an example to show how mathematically powered digital systems camouflage dangerous assumptions and modify people's behaviors.

Developed by a commercial consultancy, IMPACT was initiated in 2009 and is still in use today. It is a digital black box because its algorithms have to be complex enough to deal with complicated real-world problems (p. iv) and because its contents are "a fiercely guarded corporate secret" (p. vi). This black box prevents teachers from pressing into the details of the arbitrary scores they get from IMPACT; all that they can do is to cater to the general assumptions of IMPACT, that is, counting the students" standardized test scores heavily as the indicator of educational progress and teacher effectiveness. This double reduction draws on "historical salient measures of success" (Marcelino, etc., 2018, p. 4), that is, standardized test scores, and a too small data pool, "to score a teacher's effectiveness by analyzing the test results of only 25 or 30 students. This approach is statistically unsound, even laughable" (O'Neil, 2017, p. v). In fact, it leads to the repetition of historical inequalities and the creation of problematic teaching norms.

For example, in the 2010—2011 school year, a teacher who was very positively reviewed by the school administrators and the community received a miserable overall evaluation because she was judged as "bad" by the algorithm and because the algorithm-generated score outweighed all other factors in the IMPACT formula. She was fired by the district but then "promptly landed a position at a school in an affluent district in northern Virginia" since "she had plenty of people, including her principal, to vouch for her as a teacher" (p. viii). Here, the historical inequalities repeat themselves: Digital programs excel at dealing with large numbers at a low cost, so algorithms trained with historical data (which bear established prejudices) are always targeting the less-privileged masses; "the wealthy, by contrast, often benefit from personal input" (p. vi). O'Neil comments, "thanks to a highly questionable model, a poor school lost a good teacher, a rich school, which didn't fire people on the basis of their students' scores, gained one" (p. viii).

Also, like an algorithmic god, IMPACT affects the employment and compensation status of teachers through decisions beyond dispute or appeal. With the belief that they “simply have to work hard, follow the rules, pray that the model registers and appreciates their efforts,” “good” teachers have been cultivated to be those who know how to please algorithms. Publishers of the District of Columbia Comprehensive Assessment Systems found an unusually high rate of answer sheet corrections in spring 2010, which indicated a possibility of cheating. Under the microscope of the D.C/Federal investigation and media exposure[6], school officials stood by the test scores, gesturing not only to a belief in the integrity of the test but also to a denial of IMPACT’s risky normalizations of teachers and teaching. Finally, the erasures were deemed as “suggestive,” and the math-powered algorithm retained its sovereignty. O’Neil poignantly remarks (p. viii),

> An algorithm processes a slew of statistics and comes up with a probability that a certain person *might* [emphasis original] be a bad hire, a risky borrower, a terrorist, or a miserable teacher. That probability is distilled into a score, which can turn someone’s life upside down. And yet when the person fights back, “suggestive” countervailing evidence simply won’t cut it. The case must be ironclad.

c) Marketization featured with the grassroots users’ voluntary contribution and self-responsibilization

Founded by Harvard and MIT in 2012, edX is one of the most influential digital platforms of higher education, which so far has availed “twenty-four million more learners’ of online courses from “the majority of top-ranked universities and industry-leading companies in the world” (edX, 2020). It commits to closing educational gaps caused by space, time, and cost, as manifested by the “three central pillars” of its mission: “expanding access to high quality education to everyone, anywhere,” “reimaging education both on-campus and online,” and “improving teaching and learning outcomes through research” (edX, 2020).

“Reimaging education” means opening education to “everyone, anywhere,” namely, collapsing the economic and distance barriers of education which have been “materially” built. However, as previously discussed, it is illusive to regard the digital space as “virtual,” homogeneous, and universally accessible. The digital space is an assemblage of “multifarious yet connected spaces,” like “pictures and videos of the desks, computers, offices and bedrooms in which students actually take part in distance education” (Bayne et al, 2012, as cited in Knox, 2016, p. 311). Indeed, the digital space is full of histories and power dynamics. “Reimaging education” also means accessing classes at any time. But the networked digital world has a networked time system that eradicates other possibilities of temporality. Rather than freeing students from the constraints of the school calendar and class schedule, “the self-directing and autonomous student…is substituted for the clock-time” (p. 316). Moreover, “reimaging education” means optimizing teaching and learning based on the real-time data collected by a web algorithm. EdX takes as default that it is entitled to recording its users’ activities: “EdX and its members use cookies and other tracking technologies for performance, analytics, and marketing purposes. By using this website, you accept this use” (edX, 2020). In this way, the users work for free to help the platform “conduct experiments, exploring how students learn and how faculty can best teach using a variety of novel tools and techniques” (edX, 2020).

EdX is an attempt of the leading power of higher education to territorialize the digital realm. With its promise that the “best” educational resources are now at the disposal of individuals who might scarcely have any chance to attend the “top-ranked universities” in person, it requires learners to, not only being willing to, but also to be wise with how to enhance themselves for market needs. Meanwhile, through the voluntary contribution of the grassroots users, the platform harvests data and conducts experiments, enabling universities and companies to improve services and maintain competitiveness. However, the gap between the "virtual" and "actual" learning and learners becomes widened than diminished, since the on-campus experience at elite universities is the "core" product that would never be replicated to serve the public.

The above sections outline the frequently considered problems in the digitalization of education: the digital (use) divide, the digital black box and marketization. The following explores how these problems have been historically addressed.

1.2.2 Efforts to Address Problems in Relation to Digitalization: The Need to Reconceptualize the "Subject" and "Space"

Current research tends to focus on contextualizing digital technologies for better teaching, learning and administration. Some scholars find it important to clarify the overall direction of such a focus. For instance, Kelly (2005) relates education's inefficacy in capturing the potential of digital technologies to the highly fragmented and political nature of education markets. Seeing commercial digital products as a gold mine that education needs to dig into, she proposes close collaborations of educational institutions, the academic and the commercial research community, and the coherent national programs that make such collaborations possible. Tobias et al. (2015) believe game playing results in neural, cognitive changes "dealing with perception, attention, mental rotation, task switching, and executive control" (p. 5) and regard the common ground between the fun and learning aspects of digital games as underlying cognitive similarities. Therefore, to increase the educational value of digital games means to increase "the degree to which they stimulate deeper, or more frequent cognitive processing of instructional input" (p. 9).

Dillenbourg (2016) identifies six trends of the evolution of Artificial Intelligence in Education (AIED)—the digital-physical blur; the development of probabilistic approaches to interpreting behavioral dust; the resurgence of social cognition theories and collaborative learning; the "less design" on the end of system developers; the opening-up of systems in terms of access/source/user contributions; and more opportunities for teacher interventions. He argues that attention should be paid to the moments when "a new technology and a new vision of learning" (p. 557) converge, and to the complementarity of new and existing AI approaches. Luckin and Holmes (2016) propose what AI could offer learning currently and in the future. For example, AI models[7] provide personal tutoring, adaptive class planning and group formation, and authentic learning environments. Such models are believed to have the power to innovate educational assessment, embody new insights from the learning sciences, and create lifelong learning partners. Spector (2016) provides a preliminary framework for ethical decision-making regarding the implementation of educational technologies, especially in relation to the exacerbation of the digital (use) divide. His framework contains five interacting dimensions: common values, people/stakeholders, context, technology, and ethical principles, all of which work together to help with decision-making in complex situations.

Experiments on "how-to-use" also contribute to the problem of contextualizing digital technologies for specific educational purposes. For example, to improve teacher efficacy, an AI-driven assistant can reduce educators' administrative burden (Baker et al., 2019; Bryant et al., 2020), facilitate class planning (Luckin & Holmes, 2017), and answer routine questions (Eicher et al., 2018). To customize the learning process, the intelligent learning system extrapolates an unprecedently detailed profile of students based on which it offers real-time activities, assessments, and interventions (Almohammadi et al., 2017), sometimes in the form of a virtual learning partner as the “more knowledgeable other” (Guilherme, 2017). To boost learner engagement, the digitally enhanced immersive interface enables multiple perspectives and situated learning (Dede, 2009; Hassani et al., 2013), like an AR book (Altinpulluk & Kesim, 2016) or AR games (Barab et al., 2010; Becker, 2017; Fotaris et al., 2017; Pellas et al, 2018), which appeal to learners of all ages. To promote mental wellbeing, a computer system can learn the speech patterns and (con)textual clues to assess and prevent suicide (Pestian et al, 2016) or to reduce violence and conflict resulting from miscommunication (Honkela, 2017). Moreover, an avatar of a victim of school bullying can be used to inform real victims of conflict resolution skills as well as to cultivate empathy in non-involved students (Vannini et al., 2011). To support special needs education, social robots can repeatedly simulate behaviors in real human life to familiarize autistic children with social rules (Rudy, 2020) and to help them establish positive relations with other peers (Hao, 2020).

Meanwhile, serious concerns have been raised about the prejudice built into the digital black box. Studies have shown that the digitalization of education is not a neutral endeavor by unveiling the historical and geographical limitations inherent in algorithms (Barocas et al., 2013; Amoore & Piotukh, 2015), the making of “informational person” through the predictive analytics (Pariser, 2011; MacKenzie, 2015; Koopman, 2019; Macgilchrist, 2019), the politics embodied in data interpretation (Nguyen et al., 2019; Dyment et al, 2020), the perpetual fabrication of “truth” out of fragments of information flows (Peters et al., 2018), the complex “representations” of data in the software-based curriculum development (Edwards, 2015), the urgent need to acquire computational literacy (Bowker, 2005; Berry, 2011; Naughton, 2012), and the hot debates over the change of ethical codes, responsibilities, and accountabilities of educational professionals regarding the risk of algorithmic instrumentality (Fenwick & Edwards, 2016; Krishna, 2018).

Another inventory of critics locates the impulse to digitalize education in the marketizing agenda of late capitalism. To take the U.S. as an example, Loveless et al. (2016) name the institutional "iron-triangle" that has produced the education-industrial complex: public schools, state offices, and private corporations. Seeing data as the "new oil" (Arthur, 2013) in a "bio-informational" (Peters, 2012), capitalist society, private corporations invest in data-driven educational paradigms and are turning teachers into technicians as well as reinforcing "standardization movements with rote lines of curriculum that equate 21st century skills to the labor needs of corporations" (Loveless et al., 2016, p. xxi). In the face of the digital barons' propaganda of technological solutionism, which designates digital technologies as instruments reducing educational inequalities and developing students' workforce competencies (Bybee & Fuchs, 2006; Morozov, 2013), scholars are dedicated to unearthing the monetization of data in the digitalization of education and the consequences of education's datafication: The distinction between learner and consumer and between worker and producer gets blurred (Williamson, 2015; Fenwick & Edwards, 2016; Birch & Artyushina, 2020); The "always-on" collection and analysis of data perform new forms of surveillance and endanger users' privacy (Drachsler & Greller, 2016; Harwell, 2020); The efficiency and profit-oriented digital technologies reduce pedagogies into autonomous systems of behavior modification and promote competitive individualism that allocates responsibilities for social problems to the self (Gulson & Webb, 2018; Jarke & Breiter, 2019; Knox et al., 2020). Also, studies claim that the de-humanizing digital operation threatens the core value of modern education—the assumed "humanity" of students, and advocate the entanglement between the "physical" and digital, or between the human body, spaces, time, activities and curriculum (Hayes, 2017; Jandrić et al, 2017; Ryberg et al., 2018). Additionally, the rocketing demands for digital support in post-Covid-19 education raise serious concerns about the redefinition of teaching and learning and about the purpose and future of education (Teräs et al., 2020).

Twenty years have passed since Spector (2001) outlined the key issues that prevent "networked learning environments and highly interactive multimedia" (p. 28) from fully realizing their educational potentialities: careless migration to new technology without sufficient consideration of the contextual needs, technification that refrains stakeholders other than technicians from accessing the machine mechanism, and "restrictive institutional practices and short-sighted policy planning" as the outcome of politics among different interest groups (p. 33). A predominant aspect of existing studies, as exemplified above, are the noble efforts to understand and cope with these issues at different sites from different angles. However, these efforts leave untouched the philosophical bearings of "human" as the cornerstone of modern education. For example, a study found teacher candidates' beliefs about preschoolers' digital technology and media skills do not match preschoolers' observed skills (Mourlam et al., 2018). This study focused on the change of skills rather than the making of different kinds of teachers/learners through the change of skills. Accompanying the naturalization of "human" is the indifference to the paradigmatic change of "space." In a study on the visual composition of education space created by two digital platforms, more radical conceptualizations of meeting are proposed but the learner is still seen as a self-contained, independent "traveler" moving across various spaces (Sheail, 2015). The consequence is,

> where agency is attributed exclusively to the human subject, and space is cast as the passive backdrop to individual and social activity, the binary of absence/presence is maintained. In other words, the notion of bounded and regional

> space that is external to "us" creates the very conditions of exclusion and inaccessibility (Knox, 2016, p. 312).

It is the detachment of the subject from the backdrop of space and the maintenance of the human "agency" that pose the need for research that approaches the persistent and emerging problems in the digitalization of education by reconceptualizing human and space. In this context, Teräs and his colleagues (2020) ask the difficult question of education's future after the pandemic: "Will they [educational institutions] reinforce capitalist instrumental view of education or promote holistic human growth?" (p. 863). To explore the question, it is worthwhile, first and foremost, to clarify what is meant by "human."

1.3 THEORETICAL FRAMEWORK: FOUCAULT, WYNTER AND DELEUZE

As noted above, selected works of Michel Foucault, Sylvia Wynter and Gilles Deleuze constitute the lines of reasoning to draw upon in this dissertation. This reasoning makes it possible to trace the effects of digitalization (as a context in which modern education is now situated) in relation to what such processes are doing to reconfigure the "subject" and "space." First, I draw on Foucault's historiography of the "subject," which regards Descartes and Kant as the two "reference points" marking the historical reconfiguration in theories of subjectivation. In so doing I illustrate that it is the humanist subject, Man, and the Newtonian concept of space that have resulted in the formation of "modern" disciplines in general and "modern" education in particular. Second, based on Wynter's analytics of the "central ethnoclass Man vs. human struggle," I make clear that problems persistent in "modern" education are to be understood in relation to Man. Third, with a close look at digitalization, I mean to show the reconfiguration of Man through digitalization. I also demonstrate that education needs to turn to a theory of subjectivation to address such reconfigurations in the theories of the "subject" and "space." Last, through a careful examination of Deleuze's theory of subjectivation, I show the unique affordances it offers to the digitalizing project of education as a theoretical framework and a methodology. These affordances have ethical implicatures for educational problems and issues pertaining to digitalization.

1.3.1 Foucault's Historiography of the Subject and Wynter's Analytics of Man: The Co-constitution of Man and "Modern" Education

In his work *The Hermeneutics of the Subject* (2005), Foucault specifies two "reference points," "the 'Cartesian moment'" (p. 68) and "the supplementary twist in Kant" (p. 190). These reference points are the summit of "a whole series of complex transformations" through which a transcendental, "rational," and "capable-of-truth" subject called Man is formed (p. 190). He writes, "To be capable of truth you only have to open your eyes and to reason soundly and honestly…The subject, then, does not have to transform himself…this is very clear in Descartes," and "in Kant…what we cannot know is precisely the structure itself of the knowing subject" (p. 190).

A close look at Descartes reveals the subject's ascension to the world's summit from its restricted spot in the world. Descartes' renowned principle of existence— "*I am thinking therefore I exist [Cogito ergo sum]* [emphasis original]" (1637/2006, p. 28)—is often viewed as a circular reasoning since it ends with an "*I*" that is existing by starting with an "*I*" that is thinking. However, this principle is perfectly meaningful if "thinking" refers to investigating the law of nature, or recognizing the reason that organizes the world, and "existing" refers to living through the trifles of life. Here "thinking" tears apart the subject, elevating the thinking "*I*" to a divine positionality where human reason, of the same nature and function as God's, is responsible for knowing everything grounded in the world, including the existing "*I*."

The "maximum tension between the self as reason…and the self as individual component, placed here and there in the world" (Foucault, 2005, p. 279) sets the foundation of the humanities and the social sciences, where inquiries into "the self as individual component" are legitimized by, carried out through, and directed toward "the self as reason," i.e., the rational subject called Man. Education became established as a modern science when it was anchored to Man. The fact that "modern" and "scientized" education takes Man as its presumption, path, and goal is perhaps no better explicated in any other narration than in Kant's. For Kant, the Cartesian distinction between "thinking" and "existing" subjects is confusing, as Descartes reduces thought—the effect of the transcendental self—to the essence of mind, the properties of a mere substance. In other words, Kant thinks the Cartesian understanding of "reason" is still not impersonal and "transcendental" enough to be of ontological and epistemological significance, so he advocates a "pure original unchangeable consciousness" without which "no cognitions can occur in us, no connection and unity among them" (1781/2000, p. 232). This consciousness, the reason of the transcendental subject, is the condition for the existence and knowledge of the empirical subject, which is the distinctive and transforming object of experience. Ontologically, the consciousness distinguishes Man from its Others, the non-Man or less-than-Man. As Kant points, "Animals are by their instinct all that they ever can be…But man needs *a reason of his own* [emphasis original]" (1900, p. 2). Epistemologically, Man prescribes the protocol of knowledge acquisition: Education would not even be possible without acknowledging and following this protocol, "…education must not merely proceed by way of reasoning, but must be, in a certain sense, mechanical" (p. 22).

The consolidation of the concept, Man, in Descartes and Kant is by no means an accident; it is an attempt to address the specific problems of their historical context—the authority of the monarch and the Catholic Church in Europe during the 17th and 18th centuries. With European colonization and the subsequent U.S. dominance, Man, nevertheless, has endured and bloomed globally. Davies concisely summarizes, "Humanity, the humanistic "Man" (always singular, always in the present tense), inhabits not a time or a place but a condition, timeless and unlocalized" (1997, p. 23). Man's becoming "timeless and unlocalized" has consequences[8]: it "over-represents itself as human" (Wynter, 2003; Weheliye, 2014), regarding as less worthy or less civilized other possibilities of subject-making and knowledge production, which are, just like Man itself is, genuine responses to the localities that they emerge from.

"The history of modernity and of modern disciplinary knowledge," Lowe and Manjapra hold, "are…a history of modern European forms monopolizing the definition of the human and placing other variations at a distance from the human" (2019, p. 23). As the "gene" of modern disciplines, Man drafts the starting point, life trajectories and fatal problems of these disciplines. This is why in Lorde's formulation, the institutional inequalities attributed to gender could not be tackled by "difference of race, sexuality, class and age," for "only the most narrow parameters of change are possible and allowable" when "the tools of a racist patriarchy are used to examine the fruits of that same patriarchy" (1984/2007, p. 110). Or, in Wynter's follow-up, the "master's tools," such as notions of race, gender, and sexuality, will never dismantle the "master's house," Man. She states, "I am trying to insist that 'race' is really a code-word for 'genre.' Our issue is not the issue of 'race.' Our issue is the issue of the genre of 'Man.' It is the issue of the 'genre' of 'Man' that causes all the '-isms.'" (2006, p. 24).

Wynter gives illuminating insight into global patterns of injustice when she steers the attention to the "central ethnoclass Man vs. human struggle" (2003, p. 261):

> Our now immensely large-scale systemic injustices, as extended across the planet, are all themselves as law-likely and co-relatedly indispensable to the

> institutionalization of our now purely secular and therefore Western and Westernized liberal/neoliberal Man's homo oeconomicus's biocosmogonically chartering origin narrative! (McKittrick, 2015, p. 38)

The "-isms" caused by the issue of the "genre" of "Man,"—such as colonialism, racism, sexism, ableism, classism—have been ingrained in "modern" education ever since it was launched, like in the early stages of public schooling, "when the vast majority of children never used to go to school, being forced by law to attend a school building in order to be better 'civilized' or being prevented from going when desired (i.e., after being labeled as a less-than-human, ineducable, or 'savage') became part of the fabric called life" (Baker & Wang, 2019, p.1). Man is practiced in "modern" education as the only available mode of complete humanness for the purpose of inclusion, exclusion, tracking and assessment. Right here arises the extreme violence, the massacre committed at the ontological and epistemological level, named variably by different scholars as "global linguistic genocide" (Skutnabb-Kangas, 2000) or "epistemicide" (Paraskeva, 2015). For example, Montgomery and Colwell's book *Objects of Survivance: A Material History of the American Indian School Experience* (2019) offers a glimpse into the violence of Man epitomized in the forced assimilation of Native American children through the U.S. government's education system a century ago. It interprets a selection of photographs taken by Bratley when he worked as a teacher at multiple Native American boarding schools from 1893 to 1903, so as to reveal the otherwise concealed struggles of Native peoples for their chance to live as other-than-Man. The following figure, a cartoon drawn by "a friend of Bratley's," shows "Turning Eagle [the chief of the Lakota tribe] attempting to kill Bratley because he had threatened to shore off Kittie Turning Eagle's hair" (p. 148).

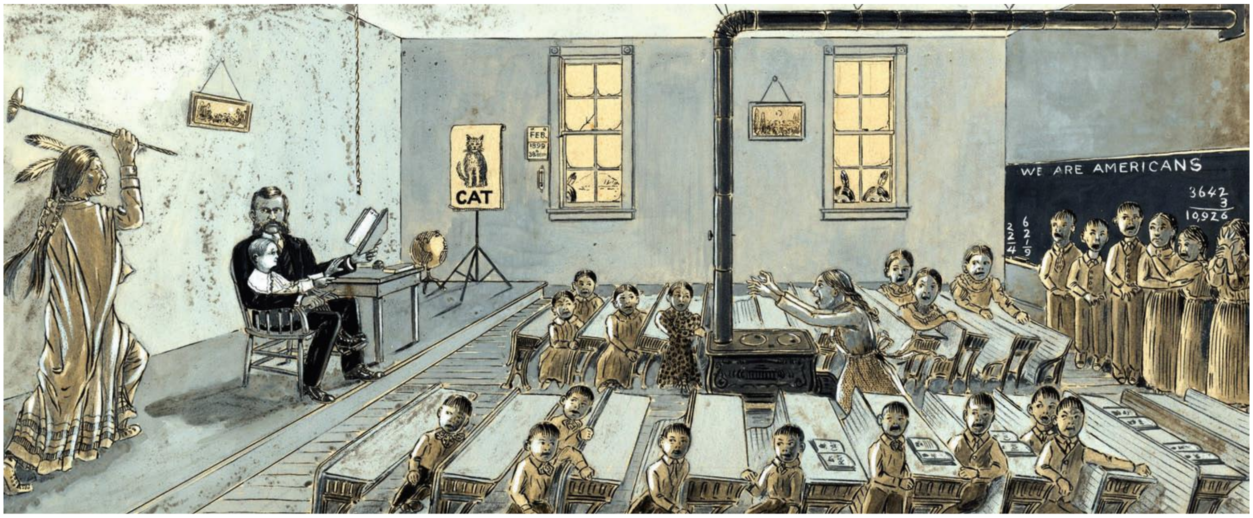

Fig. 1 A Fight over Becoming "Americans" (Montgomery & Colwell, 2019, p. 148)

Education, as demonstrated in this cartoon, refers to "Americanize" or "Anglicize" the Native child by eradicating the "savageness" he bears, or succinctly put, to "kill the Indian in him and save the man" (Pratt, 1892/1973, p. 46). Because "hair is an important part of Lakota Sioux identity and is believed to be infused with an individual's *ni* (spirit)" (p. 147), cutting hair without following the right customs, for Turning Eagle, literally was to "kill the Indian." While for Bratley, the missionary of "modernity" and "civilization," cutting hair was an issue of sanitation, and hence an effort to "save the man." The fierce conflict between Turning Eagle and Bratley, without any suspense, concluded with the triumph of Man over its Others. The chief was put in jail and his daughter Kittie, after surrendering to an Anglicized name, clothes and "knowledge," again conceded her hair as part of her spirit and identity: She returned to school "with a clean head of hair and it was kept clean thereafter" (p. 148).

Man prevails, and despite the short history of his prevalence, Man dreams to retain his glory forever. Lyotard (1997) sketches out a "postmodern fable" in which human descendants survive the death of the Sun by fleeing to the void of the deep cosmos and re-establishing extraterrestrial "liberal democracies." Such a "redemption" could only happen when a human stayed along the track of Man: He progressed and was eventually emancipated through the full development of reason, as the grand project of Humanity in the Enlightenment confidently promises. The tricky part for Lyotard is, with all the cutting-edge sciences and technologies that prepare the "human" for the future survival, is it still the same "human" that ultimately becomes capable of existence at the end of time (p. 91)?

His answer is radical. He believes it is *energy*, rather than the subject of history (let alone Man), that keeps on living, "The hero is not a subject. The word energy…. knows nothing and does not *want* [emphasis original] any of it. It obeys blind, local laws and chance" (p. 93). Though skeptical about his substitution of one meta-word, energy, for another, subject, this work agrees that Man does not stand the changing conditions. The next section theorizes space in relation to Man, exploring the historical and philosophical intertwinement of Man and the conception of space.

1.3.2 Theorizing Space in Relation to Man

The concept of "space" is more a recent formation within "Western" culture, as the discourses it draws upon—the polyphonies categorized as the Greek thought—are debating mainly "where the thing/body is," "where it is NOT," and "what it is that always is," instead of proffering a coherent proto idea of what we now call "space." The spherical model of the universe, proposed by Pythagoras (Dicks, 1985) and developed by Aristotle (Aristotle, 2008), highlights boundedness over infinity[9], thus orienting discussions less to a holistic and limitless background where all changes take place than to the non/occupation of the thing/body of somewhere and the essential properties of the thing/body, namely, "place" (*tópos*; ancient Greek: *τόπος*), "void" (*kenon*; ancient Greek: *κευου*), and "thing/body-ness" (*chora*; ancient Greek: *χώρα*). As Cornford (1975, as cited in Capek) explains, Anaximander"s *"πέρας"* (*apeiron*) is neither "boundless…in the sense of three-dimensional infinity" nor "qualitatively indeterminate," as most other historians understand; rather, this term applies to "the two-dimensional boundlessness of a ring," indicating "a part of the pre-Euclidian common sense; its space was psychological or physiological which by its own nature was bounded, geocentric (or, rather, "bodycentric") and heterogeneous" (p. xviii-xix).

A few threads need to be pulled on in order to weave the transition from an assembly of concepts like "place," "void," and "thing/body-ness" to the construction of a "space" as part of our current unconsciousness. First, Pythagoras and his followers believe that the universe is constituted by numbers and that numbers are determined by the void, which, as the *apeiron* air outside the universe, enters and exits from the universe as the universe breaths. Assuming that "the elements of numbers were elements of all things" (Fairbanks, 1898, p. 137) and that the void separates the one and continuous universe into discrete things/bodies (Aristotle, 2008, p. 91-92; Fairbanks, 1898, p. 146), the Pythagorean theories pave the way for reimagining the universe as a machine operating under mathematical rules and for valorizing the void as the determinant of the nature, the place, and the motion of things:

> The heaven is one, and that time and wind and the void which always defines the places of each thing, are introduced from the infinite. And …that place is the immovable limit of what surrounds the world, or that in which bodies abide and are moved… and motions arise according to place of bodies that surround and oppose each other… (p. 146)

Second, Plato in his *Timaeus* (2008) explains the creation of our tangible world as a process in which the craftsman-god, who is good and eternal, molds out of "the receptacle of all material bodies" something that "bears the whole multifarious range of visible qualities" (p. 43). Three players are in charge of what comes to be viewed as corporeal and changing: "The maker and father of this universe of ours, and even if we did find him, it would be impossible to speak of him to everyone" (p. 17), "the class of things which are unchanging, uncreated, and undying" (p. 44) and of which the perceptible and in-motion things are but copies, and the *chora*, or "something of this sort" (p. 41), which sustains as the "raw" and characterless stuff making up the ephemeral phenomenon. That Plato uses *chora* (translated into English as "space") to facilitate his explication of the "receptacle" shows the historical lineage of key connotations seen in Newton's conceptualization of space like "exist[ing] for ever," "indestructible," and "act[ing] as the arena for everything that is subject to creation" (p. 45), and in Descartes" prescription of space as a generic form of extension, i.e., "thing/body-ness."

Third, Aristotle starts from a "universally accepted" assumption that "existing things exist somewhere" (Aristotle, 2008, p. 78) and proceeds delineating the "somewhere," i.e., the "place" (*tópos*), and the "void," i.e., the "place deprived of body" (p. 79). What is a place? For Aristotle, a place is the "immediate container" (p. 85) of a perceptible thing, which is three-dimensional but not material, if "material" means perceptible (p. 80). Specifically, "a thing's immediate place is exact the same size as it"; a place "can be left behind by the object" (p. 85); and a place "has a certain power" (p. 79) to enable an object's natural movement in terms that it "admits of the distinction" (p. 85) between directions, like above and below, within itself and prescribes the proper place an object directs itself toward. Because "there are no distinctions within that which is void and infinite" (p. 95), an object can neither move nor stop in the void. Therefore, "there is no such thing as void" (p. 96). Aristotle's denial of "place" as a kind of extension, "the only kind of extension…is the extension of bodies" (p. 91), upon his affirmation of its reality calls for further clarification of how extension relates to reality, which Descartes and Kant attempt to offer through their construction of "space." Besides, the unevenness of the Aristotelian "place" corresponds with Einstein's proposal that spacetime is curved by matter.

Fourth, early atomists like Democritus hold that what absolutely exist and make up the perceptible world are but two realities: atoms and void: "D16. By convention sweet and by convention bitter, by convention hot, by convention cold, by convention colour; but in reality, atoms and void" (*Democritus: Fragments 16*, Taylor, 1999, p. 9). Each atom is indivisible, completely solid, and too small to be sensed; of different size, number, and ways of relating to one another, atoms come together to form perceptible objects with various appearances (Taylor, 1999). Compared with the atom which is "being," the void is "not-being." Though the well-known commentary by Simplicius treats Democritus' "void" as "space" in which atoms "travel about" (*SIMPLICIUS Commentary on De Caelo 294.33-295.36*, Taylor, 1999, pp. 70-71), Democritus himself says little except that the void, contrasted with the solid or full, is real and makes possible the movements of atoms. In response to Aristotle's critique on Democritus' "void," Epicurus picks up what Democritus left behind and explains why the void allows atoms to move: Atoms have weight and "history of contact with other atoms," thus having "impetus and inertia" to collide and change direction and speed in the void even while the "void itself remains undifferentiated" (Inwood, 1981, p. 283). Moreover, Epicurus partially incorporates Aristotle's definition of "place" to resolve the paradox that early atomists are trapped in (i.e., the void as not-being is the ultimate existent). Like Aristotle's place, the void for Epicurus is the boundary or "surrounding body" of the tangible body or thing (p. 282). Hence, it is also an entity (a being) rather than not-being, although it differs from the Aristotelian "place" in terms that it is movable and displaceable: Intangible and in lack of resistance, the void is able to "yield to atoms," escaping them like fluids letting solid objects "in" and through (p. 279). Equating "void" to "place" and regarding it as an independent entity that is as real as the tangible thing/body is prepare for the emergence of an "absolute space" existing independently of the existence of material bodies and serving as a "container/stage" where material bodies are located. Besides, the atomist account of the perceptible world as composed by different compounds of different atoms, whose movements are determined by external drives—the collision between atoms—rather than the "psychical" or reason of an intelligent universe, offers a mechanistic paradigm that post-renaissance thinkers in Europe mobilize to explain the material world.

Despite the dissonant perspectives on "place," "void," and "thing/body-ness" in ancient Geek, there is a predominant cosmology underlying such debates. This cosmology considers the physical world as a living being and the order of the physical world as the effect of the living being's Mind, reasons, motives, or Love. This Mind regulates itself and all its manifestations, human affairs and whatever else. Collingwood comments,

> The life and intelligence of creatures inhabiting the earth's surface and the regions adjacent to it…represent a specialized location organization of this all-pervading vitality and rationality [of the world of nature], so that a plant or animal, according to their ideas, participates in its own degree psychically in the life-process of the world's "soul" and intellectually in the activity of the world's "mind," no less than it participates materially in the physical organization of the world's "body" (1945, pp. 3-4)

The one-ness of the Mind and "the world's 'body'," according to Collingwood, is derived from the analogy between the human's "microcosm" and the physical world's "macrocosm," which, for the ancient Greek, is that between an organism whose mind directs its bodily activities and a world of "nature" that gives birth and grows (see the etymology of the word "nature") (p. 8). Throughout antiquity and the Middle Ages, the rise of Christianity and the popularity of machines in daily life have reconfigured the "microcosm" of Europeans, leading to "the analogy between nature as God's handiwork and the machines that are the handiwork of man" (p. 9). Now that the ancient Greek's "nature" is devitalized with its once-immanent Mind transcending all else as God, what give plausibility to the perpetual motion of the physical thing/body, besides God as the prime mover, are mechanical rules, as Kepler (1605, as cited in Capecchi, 2020) writes, "My aim is to say that the machinery of the heavens is not like a divine animal but like a clock…and that in it almost all the variety of motions is from one very simple magnetic force acting on bodies, as in the clock all motions are from a very simple weight" (p. 90). Also, such rules are backed up by mathematics, as Newton clarifies in the preface of his masterpiece *Mathematical Principles of Natural Philosophy* (1687/1974), "But I…consider chiefly those things which relate to gravity, levity, elastic force, the resistance of fluids, and the like forces…and therefore I offer this work as the mathematical principle of philosophy" (p. xvii).

Accompanying the transcendence of the Mind of the divine nature *as* God is the quest for concepts indicating eternity and infinity: "The Supreme God is a Being eternal, infinite, absolutely perfect" (Newton, 1687/1974, p. 544). Utterly imperceptible and unrepresentable (p. 545), knowable only "by his most wise and excellent contrivances of things, and final causes" (p. 546), God "exists necessarily" and "exists *always* and *everywhere* [emphasis original]" (p. 545). Thus, demanding and guaranteeing the existence of absolute time and absolute space, "he constitutes duration and space" (p. 545). Just as the Pythagorean sacralization of numbers, the Platonic formation of the craftsman-god, and the atomist's model of mechanical movement all find their contextual expressions in the mechanization and mathematization of the "macrocosm," they also contribute to the post-Renaissance construction of "time" and "space," of which the most influential is laid out by Newton: "Absolute, true, mathematical time, of itself, and from its own nature, flows equably without relation to anything external" and "absolute space, in its own nature, without relation to anything external, remains always similar and immovable" (p. 6). In Newton's framework, absolute time and absolute space exist independently of each other and of the physical object; they are real entities with their own manner of existence which is necessitated by God and differs from that of the object. Relative times and relative spaces are but the ways of measuring them. Here absolute space is defined as a great void that objects occupy but do not act upon.

Such a position is challenged by Leibniz who contends that space is not a self-subsistent entity but an idea of the relation of coexisting objects, as he argues with Newton's disciple, Clarke:

> I hold space to be something purely relative, as time is—that I hold it to be an order of coexistences, as time is an order of successions. For space denotes, in terms of possibility, an order of things that exist at the same time, considered as existing together, without entering into their particular manners of existing. And when many things are seen together, one consciously perceives this order of things among themselves (Leibniz, 1716/2000, p. 14).

For Leibniz, space and time are derivative: If all physical objects are removed, there would not be anything called "space" and "time." However, Kant (1781/2000) refutes this relationist perspective by specifying the impossibility of the "absence of space." He says, "One can never represent that there is no space, although one can very well think that there are no objects to be encountered in it. It is therefore to be regarded as the condition of the possibility of appearances, not as a determination dependent on them" (p. 158).

Dissociating himself from Leibniz, Kant asserts that space does exist as infinite magnitudes. However, such magnitudes should not be confused with Newton's "absolute space," which is an independent existent. The Kantian space and time are "forms of our sensibility, hence conditions under which objects of experience can be given at all and the fundamental principle of their representation and individuation" (p. 7). In other words, they are the *a priori* requirements of the human sensory-cognitive faculties to which the world of appearances, or the phenomenal world, is to conform, "but if the object…conforms to the constitution of our faculty of intuition, then I can very well represent this possibility [of knowing the object *a priori*] to myself" (p. 110). Kant especially looks to mathematics and geometry to verify that space is not "drawn from outer experiences" but is "the ground of all outer intuitions": "The apodictic certainty of all geometrical principles and the possibility of their *a priori* construction are grounded in this *a priori* necessity" (pp. 157-158).

Such a "Copernican" turn to "our faculty of intuition" indicates the shift of authority from God to a humanist subject, Man: God necessitates Newton's "absolute space" and "absolute time," while the pure consciousness of Man ensures Kant's space and time to be "transcendentally ideal" yet "empirically real" (p. 7). This shift is also seen in Descartes' work on space. With recourse to the Aristotelian understanding of place, Descartes defines space as a plenum of "internal place." However, in contrast to Aristotle, "internal place" for Descartes is the "immediate container" not distinguishable from the "contained": "Nor in fact does space, or internal place, differ from the corporeal substance contained in it, except in the way in which we are accustomed to *conceive* of them [*sic;* emphasis added]" (Descartes, 1644/1982, p. 43). Unlike Aristotle, who rejects the idea of place being a kind of extension, Descartes bluntly points out that space is extension in the form of "a generic unity" (p. 44) and that the object/thing is extension in the form of peculiarity. Indeed, after taking away all nonessential properties of a physical object, what remains in the idea of that object is “something extended in length, breadth, and depth; and this fact is also included in our idea of space, and not only of space which is full of bodies, but also of space which is called a void” (p. 44). It is the “thinking” subject that conceives and crafts the thing/body-ness out of the world of appearances, and grounds the reality of space. Moreover, seeing space as “length, breadth, and depth,” Descartes develops his coordinate system where space is epitomized as a plane with the coordinate axis and sets of numbers, by which the location of a point could be specified.

The Cartesian understanding of space as extension highly resonates with Einstein’s later elaboration on space: “Descartes argued somewhat on these lines: space is identical with extension, but extension is connected with bodies; thus there is no space without bodies and hence no empty space.…the general theory of relativity confirms Descartes’ conception in a roundabout way” (Einstein, 1916/2001, p. 140). The “roundabout way” taken by the general theory of relativity is to disentangle the concept of extension from the human “experiences of laying out or bringing into contact solid bodies” (p. 140) by attempting to prove that the field, which was once used to describe the state of matter as a continuum, exists as “physical reality” (p. 157). That the field could exist “in the absence of ponderable matter” (p. 148) enlarges the concept “extension” beyond “solid bodies” and furnishes Descartes’ line of reasoning:

> Thus Descartes was not so far from the truth when he believed he must exclude the existence of an empty space. The notion indeed appears absurd, as long as physical reality is seen exclusively in ponderable bodies. It requires the idea of the field as the representative of reality, in combination with the general principle of relativity, to show the true kernel of Descartes’ idea; there exists no space “empty of field” (p. 157)

Hence, for Einstein, space is inseparable from field. More accurately, it is space-time that is inseparable from field: Space must be "relative" to time so that it can sustain as a matter of fact that light travels at a constant speed for all observers regardless of their state of relative motion. Space-time, a four-dimensional manifold that can be stretched and wrapped by matter, is an attribute of field. As Einstein explains, "Space-time does not claim existence on its own, but only a structural quality of the field" (p. 157). The Einstein field equations relate the geometry of space-time to the distribution of matter within it, as beautifully summarized by Wheeler and Ford, "Spacetime tells matter how to move; matter tells spacetime how to curve" (2010, p. 2).

Einstein's theories, though being a milestone in physics, have not successfully made their way into the paradigms underlying daily experience in the wider social context (Putnam, 2001). What remains fundamental to our spatial experience is still the assumption that space is an infinite, independent, and undifferentiated container in which all things move about and act upon each other. In this view, the location and motion of things can be mathematically calculated and geometrically expressed. Such a conception of space is established and consolidated as the Mind transcends from within the intelligent universe to a panoptic supremacy as God. As Man takes over God's position and starts to incarnate the transcendental mind, it generates uneven relations of human elements that define a relational, heterogeneous space:

> As the animal that possesses reason, the human being is the intersection of horizontal temporality and a vertical linking time to eternity: the *erecti homines* are not bound to their particular place, as are the *prona animalia*. Standing up and gazing at the firmament, admiring its order, the human being transcends his or her natural place. (Harries, 2001, p. 323)

1.4 THE DIGITAL RECONGFIGURATION OF MAN: A FUNCTIONALIST, UTILITATIAN ORIENTATION

Digitalization is well-known for its inscrutability and elusiveness caused by the intricacy of computer technologies and the inventiveness with which such technologies are socialized. Edwards (2015), when talking about how software serves as the hidden curriculum in education, mentions that "the black-boxing and taken-for-grantedness is almost deliberate, designed into the [computer] technology" (p. 266). Manovich recognizes the "'meta-generative' specificity of computers," namely, the capacity of "stored-program electronic digital computers" to empower "the continual creation of new machines, opening new possibilities, through the definition of new sets of computational processes" (Wardrip-Furin, 2009, cited in Manovich, 2013, p. 103). Based on that recognition, Manovich furthers a reconceptualization of code as alive speech rather than structuralist language and promotes a unique understanding of computer literacy that highlights the ongoing "interactive experiences," or the vibrant in-betweenness of computers and their users (2020, pp. 88-89).

These "interactive experiences," the networking of all actors of the digital ecosystem, hardware and software alike, human and non-human alike, could only be analyzed and visualized, according to Manovich, by "cultural analytics," that is, by "*computational and design methods—including data visualization, media and interaction design, statistics and machine learning* [emphasis original]" (p. 9). To put it another way, digitalization could only be effectively approached by digital means because the scale and speed of data production and dissemination are far beyond the reach of the biological unit called "human:" "In my view, the only possible way to study the patterns, trends and dynamics of contemporary culture at that scale is to use data science methods" (p. 1).

The strength of “data science methods,” the translation of actual events into digits to enable a timely and accurate analysis, is meanwhile these methods’ blind spot: There is no detour around the politics of nihilating the pre-histories of the “data.” This is exactly how science cuts into our chaotic world, “science…relinquishes the infinite in order to gain reference: it lays out a plane of simply undefined coordinates that each time, through the action of partial observers, defines states of affairs, functions, or referential propositions” (Deleuze & Guattari, 1994, p. 197). Science is not interested in catching every nuance; rather, it stabilizes itself on a “partial observer” to construct reference and coordinates, to define the constant and the variable, and to extract propositions. The “partial observer” for “data science” is the reductive and reformative perceptions occurring through the standardization, classification, and “representation” of data, which cannot be surveyed unless drawing on systems operating differently from science, like art and philosophy. Science, art, and philosophy, according Deleuze and Guattari (1994), construct self-sustaining solidarity amidst chaos, “the infinite speed with which every form taking shape in it vanishes” (p. 42), by mobilizing complementary yet fundamentally disparate mechanisms. In such a case, what kind of scenario would art and philosophy imagine for digitalization?

Below are two artworks endeavoring to divulge the sneakiness of digitalization. The first (see figures 2 to 4) (Zhestkov studio, 2019) is an experimental art film called “computations,” which visualizes the basic framework of digitalization: the black-boxed computation.

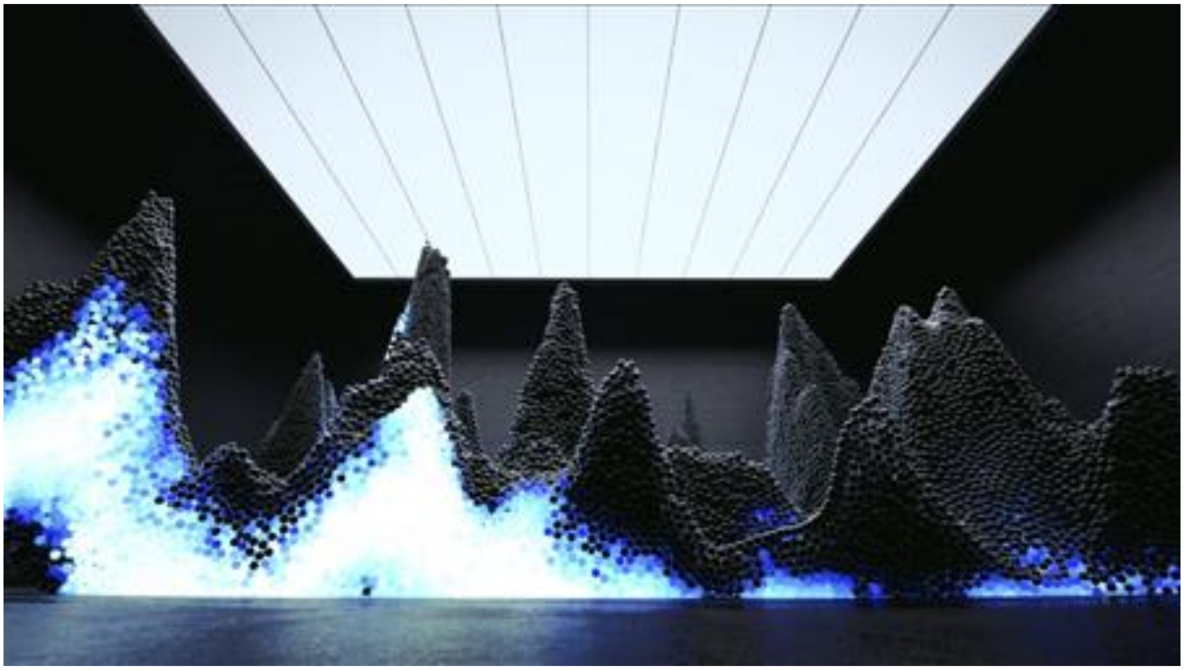

Fig. 2 “Computations” Snapshot 1 (https://zhestkov.studio/Computations-Art-film-2019)

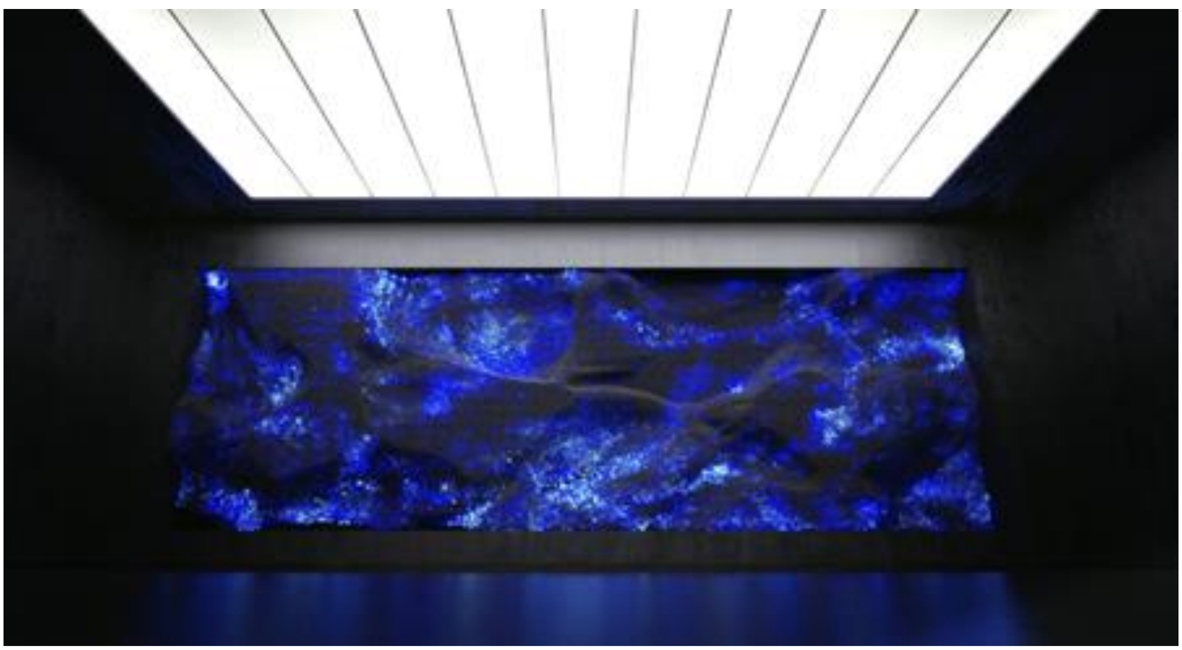

Fig. 3 “Computations” Snapshot 2 (https://zhestkov.studio/Computations-Art-film-2019)

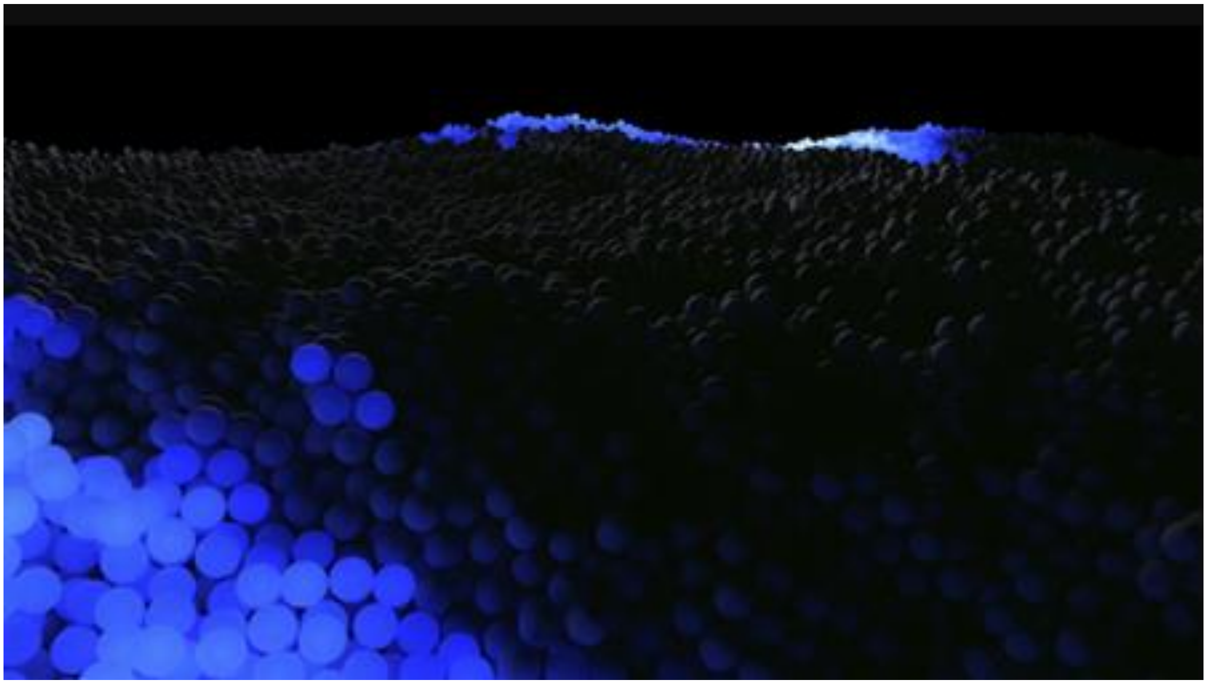

Fig. 4 “Computations” Snapshot 3 (https://zhestkov.studio/Computations-Art-film-2019)

The introduction of this film reads, “Composed of billions of particles, they [digital systems] are more than the sum of their parts—they are thinking machines that visualize, calculate, and communicate through coordinated movement and colored illuminations” (Zhestkov studio, 2019). Digital systems push “thinking” beyond the “human” scale by forming and assembling “billions of particles,” i.e., digits, through “coordinated movement and colored illuminations,” i.e., the biased instructions or models like coding, algorithms and analytics. Decision-making is no longer attributed to Man’s agency, but to the pulse of “some kind of strange computing organism,” in the words of Maxim Zhestkov, the designer and director of this film.

The second artwork (see figures 5-7) (Perceptual art, n.d.) is a sculpture named “Perceptual Shift,” which debates the very conceptualization of “perception” as a *de facto* effect of digital flows.

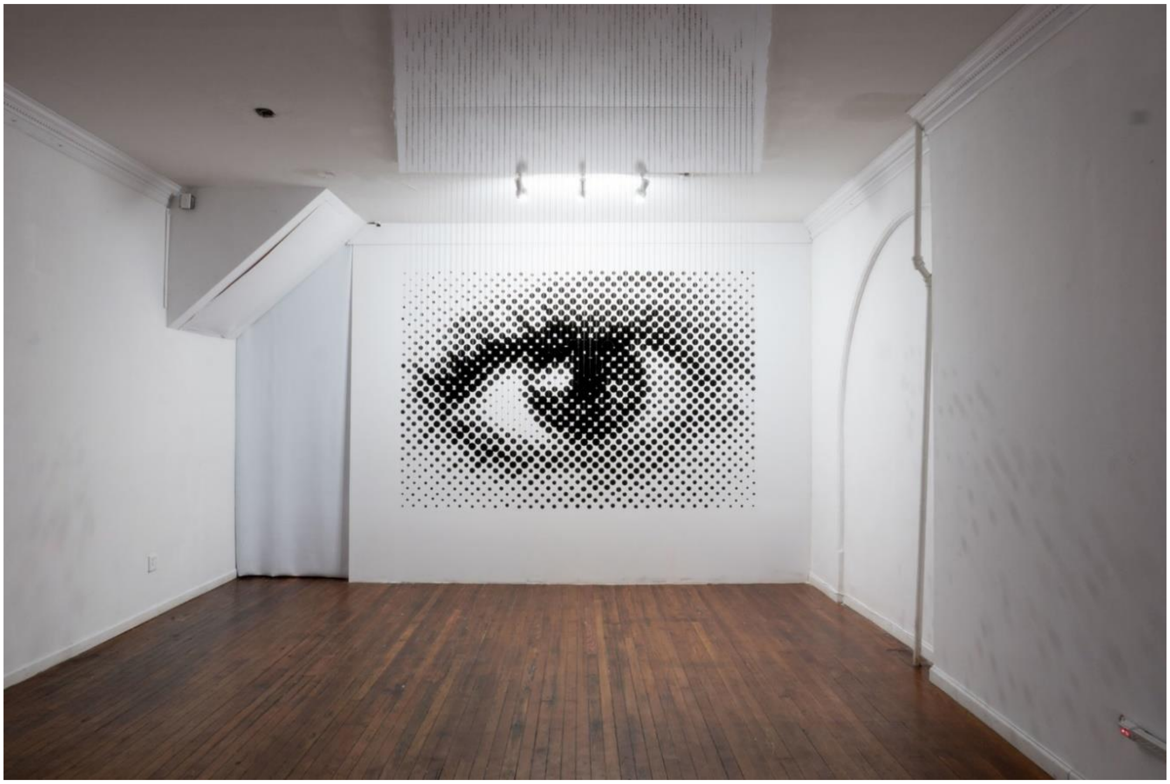

Fig. 5 “Perceptual Shift” Snapshot 1 (https://www.perceptualart.com/portfolio.html)

Fig. 6 “Perceptual Shift” Snapshot 2 (https://www.perceptualart.com/portfolio.html)

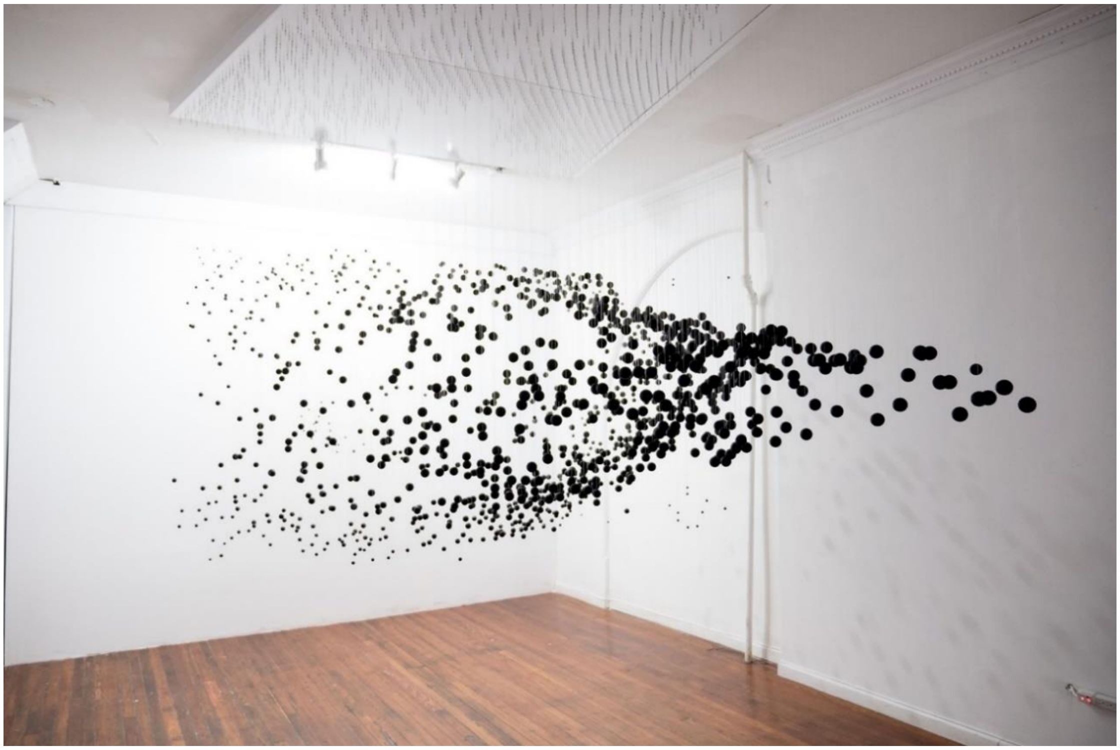

Fig. 7 “Perceptual Shift” Snapshot 3 (https://www.perceptualart.com/portfolio.html)

Figure 5 demonstrates that in “good commonsense,” perception is a faculty of (an organ) of the subject. In Figures 6 and Figure 7, the sensory organ is dissolved into the flux of homogeneous units of information, namely, that of binary digits. Thus, “perception” is dislocated from the subject, taking place whenever and wherever such fluxes are formed. Furthermore, graphically presented as dots, binary digits bear no excessive indexes except the zero/one value and assemble only as silhouettes of no depth, making up a digital two-dimensionality. This sculpture, therefore, displays bluntly the winding-together of the more-than-human perception, the digitalized, objectified subject, and flattened-up space.

Unlike “data science methods,” these two works do not operate along strictly set axes with constants and variables. Rather, they exert “control over light, color, form, and motion” (Zhestkov studio, 2019) to perform part and parcel of chaos itself in an unexpected way. Deleuze and Guattari (1994) theorize such a pioneering nature of artworks and art as follows: "blocs of sensations in the territory—colors, postures, and sounds…sketch out a total work of art" (p. 184) and "artists struggle less against chaos…than against the "cliches" of opinion…Art is not chaos but a composition of chaos that yields the vision or sensation" (p. 204). Here "*Computations*" and "*Perceptual Shift*" yield "the vision or sensation" regarding "subject," "space," and "perception" by compiling and presenting the chaos of digitalization straightforwardly, without necessarily quantifying, like science does, or qualifying the chaos, like philosophy does.

Through concepts, philosophy gives chaos some "quality" by both preserving the unthinkable speed of the chaos and carrying out thinkable movements in concrete contexts: "Science, art, and philosophy are equally creative, although only philosophy creates concepts in the strict sense" (p. 5). In other words, a philosophical concept captures the ephemeral but ceaseless transitions that the virtual, the yet-to-be, turns into the actual, hence "giv[ing] consistency to the virtual" (p. 118) "in a state of *survey* [*survol*] in relation to its components" (p. 20). To retain the unimaginable velocity and volume of digital movements and to grasp the variant actualizations of such movements in detailed circumstances at the same time, philosophy makes the concept "digitalization" "*a point of absolute survey*" that traverses "*the inseparability of a finite number of heterogeneous components*….*at infinite speed* [emphasis original]" (Deleuze and Guattari, 1994, p. 20).

Among the inseparable, heterogeneous components that "digitalization" traverses are "communication," "information," "systems," "binary digits," "data," to list a few. Claude Shannon, "The Father of the Digital Age," has reconceptualized "communication" by proposing a non-semantic definition of information. Before the publication of Shannon's (1948/1964) groundbreaking masterpiece, "The mathematical theory of communication," communication concerned the messages with *meaning*, which is tied to "certain physical or conceptual entities" but not amendable of quantification, and the fundamental problem of communication was "that of reproducing at one point either exactly or approximately a message selected at another point" (p. 31). Shannon instead interprets communication in terms of a decrease in uncertainty and holds as the key to communication the transmission and reconstruction of the probability distribution of a set of possible messages. He explicates,

> These semantic aspects of communication are irrelevant to the engineering problem. The significant aspect is that the actual message is one selected from a set of possible messages. The system must be designed to operate for each possible selection, not just the one which will actually be chosen since this is unknown at the time of design (p. 31).

In accordance with the communication system that "must be designed to operate for each possible selection," information, in Shannon's information theorems, is viewed probabilistically, completely irrelevant to the content or structure of the messages and purely quantitative. For instance, if there is only one possibility out of the set of possible messages, there is no information to be conveyed. Moreover, information not explainable or measurable in physical terms makes possible the self-organization and self-production of circular systems. Ludwig von Bertalanffy (1968) defines system as a complex of interacting elements constantly co-evolving with its environments and conceives the world as a series of systems (and systems of systems) on the levels of cells, organisms, self-regulating machinery, groups of organisms and machinery, society, and the universe. He proposes that properties of systems emerge from the interaction of elements and that common to all systems are organizing principles that can be modeled mathematically.

Similarly, Gregory Bateson (1972, 1991) describes system as "any unit containing feedback structure and therefore competent to process information" (1991, p. 260) and claims that the world is a group of systems interacting with each other. For him, the system can regulate and sustain itself only by "figuring out" the possibility of new choices based on the effects of past choices. In other words, it is the possibility distribution of choices, or information, rather than physical stimuli, that triggers and energizes the feedback loop of the system, "what we mean by information—the elementary unit of information—is a difference which makes a difference" (Bateson, 1972, p. 453).

While "information" on the analytical level must be properly translated into a form that is efficient for movement or processing in the engineering of communication systems. Shannon and others who laid the foundation for the communication infrastructure underlying the socio-technological movement of digitalization, like Nobert Wiener, agree that the quantitative modeling of information works most naturally, efficiently in a binary digit (a 1 or a 0), which articulates uncertainty as "a choice between two equally probable simple alternatives, one or the other of which is bound to happen" (Wiener, 1948/2019, p. 86). Wiener comments, "in accordance with the policy adopted in some existing apparatus of the Bell Telephone Laboratories, it would probably be more economical in apparatus to adopt the scale of two for addition and multiplication, rather than the scale of ten" (p. 7). As binary digit formats underlie computing devices that perform arithmetic, controlling, storing, and input/output operations, including but not limited to the Central Process Unit (CPU), semiconductor memories, flash drives, compact disks, etc., "data" relative to digital technology refers to information converted into binary digit form that makes possible computer systems' self-referenced operation, "all the data, numerical or logical, put into the machine are in the form of a set of choices between two alternatives, and all the operations on the data take the form of making a set of new choices depend on a set of old choices" (Wiener, 1948/2019, p. 163).

Here, the philosophical investigation of digitalization takes digitalization as traversing the inseparability of a finite number of heterogenous components, i.e., "communication," "information," "system," "binary digits," and "data." It reveals that digitalization, through every bit of its efforts, attempts to envision, design, build, and use what Penny (1994) calls the "cognitive feedback loop:" From data practices of generation, storage, cleaning, analysis and prediction arises the mind that perceives, memorizes, selects, thinks, and acts; the outcomes of the mind's actions, in turn, become incoming data that restructure the mind and address a changing "reality." This distributed, disembodied mind does not overcome the body but encodes the body into patterns of information and dictates the production of desirable bodies/body images for preset goals (always for the sake of profit, surveillance, and control). Therefore, digitalization is a continuation and culmination of the Cartesian-Kantian mind-body duality, only with a functionalist (substrate-independent), utilitarian (engineering-ready) twist. As noted by Foucault (1989, 2005) and Wynter (2003, 2006), Man has incarnated the transcendental mind through intellectual movements called humanism, it can be said that digitalization brings about a functionalist, utilitarian orientation to Man. This orientation, for example, is described by Benjamin (2019) as the "New Jim Code:" The ontological divisions generated by Man (as exemplified by race) and the discriminations they ground (as exemplified by racism) are coded/informatized, black boxed, and engineered by digital technology.

Consistent with the functionalist, utilitarian orientation to Man is the functionalist, utilitarian orientation to the production of space through digital technology. First, space is increasingly informatized and digitally engineered, as evidenced by the current trend towards developing more intelligent, flexible and user-friendly human-machine interfaces and uploading "physical" sites in the computer storage and the internet. Penny (1994) describes the very desire to create "virtual" spaces as a cultural practice, "the construction of more and more complex and expensive interfaces is…the kind of obsessive project that characterizes the activities of engineers in the realm of cultural production" (n. p.). Here what is (re)produced culturally is "a humanist world view" (n. p.) which separates the mind and the body and places the body under the command of the mind. Dillenbourg (2016) reminds educators that the digitalization of educational spaces is not an option, ""I expect the digital-physical issue to become obsolete in the future. Instead, I expect researchers to have a global view that could be called 'the classroom is the [digital] system'" (p. 548). Second, the continuous interactive digital representation black boxes the cultural codes of Man as natural, automatic, and inevitable, and creates bodies whose spatial experience is carefully planned, calculated, edited, and thus restricted. It is in this sense that Penny calls the "virtual" spaces a gap or gulf "between the viewer and the viewed, with no potential of active interplay" (n. p.). Knox (2016) shows how the leading online learning platforms like Coursera and edX are spaces of infinite patches of "surfaces" created through the black box of digitalization. Coursera and edX use images of the prestigious university campus to mark the "virtual" space they create as offering equal access to the once exclusive, "elite" educational sites. However, the "open" "virtual" space is discriminatively produced from IP address data (p. 312), and the institutional façade are but "the transparent window through which the prestigious campus is seen" (p. 311) but rarely entered and lived within.

Both artistic and philosophical explorations of digitalization indicate that the humanist subject, or Man, which is rational and autonomous, is reconfigured as space becomes infinite patches of "surfaces" created through the black box of digitalization. This shift of "subject-space" cannot be emphasized enough. Indeed, "modern" education, though situated in digitalization, adheres to the making of Man and maintains the Newtonian, container-like space. Education needs a theory of subjectivation to help it deal with problems complicated by such a reconfiguration of "subject-space" posed by digitalization. The following section discusses what affordances Deleuze's theory of subjectivity offers in regard to what is happening in regard to the "subject" and "space" in the digitalization of education.

1.4.1 "Subject-Space" via Deleuze: Both a Theoretical Framework and a Methodology

> In the mind, space and time were only a composition.
>
> GILLES DELEUZE, *Empiricism and Subjectivity*

Mainly drawing on Hume and Bergson, Deleuze develops his tripartite narratives of space, time and subject: "Actualization takes place in three series: Space, time and also consciousness. Every spatio-temporal dynamism is accompanied by the emergence of an elementary consciousness" (Deleuze, 1994, p. 220). Space, time, the forming of "I," and the mind which space and time configurate have to be considered together.

The mind here should by no means be confused with the psycho-organic complex related with the organ called the "brain"; it is rather "a given collection of impressions and separate ideas" (Deleuze, 1991, p. 132). Impressions, together with reproductions of impressions, and ideas, are "simple elements…minima…indivisibles" (p. 26), or sensible points, "visible and tangible, colored and solid," having "no extension" yet existing. They are midpoints between real extension (a physical point) and nonexistence (a mathematical point) and are the only *real* ones. Again, "sensible" refers not to the capacity of being "felt" by an organism but by other impressions or ideas. Thus, an impression or idea senses and is sensed as "total objective prehensions" (Deleuze, 1986, p. 64), like light that diffuses "without resistance and without loss" (p. 32). In a Deleuze-Humean term, an impression or idea is an atom, which "perceives infinitely… from the point where the actions which are exercised on it begin, to the point where the actions which it emits go" (p. 64). Alternatively, in a Deleuze-Bergsonian term, it is an image, a movement[10], which "act[s] through every one of its points upon all the points of all other images, transmit[s] the whole of what it receives, oppose[s] to every action an equal and contrary reaction" (Bergson, 1991, p. 36).

Neither in the idea nor in the bond of ideas is there constancy or uniformity: "The movement of ideas" and "the totality of their actions and reactions" are "whimsical and delirious" (Deleuze, 1991, p. 23). Such a delirium or madness is called the mind, or the imagination, and is of "two objective characteristics: indivisibility of an element and distribution of elements," referring respectively to the mind's "temporal, and sometimes spatial, appearance" (p. 92). In other words, it is not the mind that is in time and space, but time and space are in the mind: The idea of time is the idea of "a continual succession of perceptions[11]," while the idea of space is the idea of "visible or tangible points distributed in a certain order" (pp. 91-92).

To constitute the "whimsical and delirious" motion of impressions and ideas (mover and motion indistinguishable from each other), which is described by Deleuze as "a psychology of the mind," is "not at all possible, since this psychology cannot find in its objects the required constancy or universality" (p. 21). What matters for Deleuze, as he agrees with Hume, is "a psychology of the mind's affections" (p. 21), namely, how the mind has acquired a tendency, a set of conditions, that structures its perceptions and reactions. For him, "affections… unveil the idea of subjectivity…Consequently, the psychology of affections becomes the philosophy of the constituted subject" (p. 30): With love and hate, joy and sadness, the subject is disposed to do something than others. This interpretation resonates with Deleuze's reading of Bergson, where he calls the subject the “living image” or the “center of indetermination” (Deleuze, 1986, p. 65). In this view, the subject, instead of reacting to everything else upon receiving it, “hesitates” before reacting.

But how does the mind become the subject? At first sight the subject is a structure that transcends the mind: “Literally, the subject goes beyond what the mind gives it: I believe in what I have neither seen nor touched” (Deleuze, 1991, p. 24). However, this “transcendence” occurs only *inside* the mind when the mind gains a tendency through the reinforcement of specific associations like causality, resemblance and contiguity: That one idea can introduce, represent and constitute another facilitates the mind’s comfortable and “easy passage from one idea to another” (p. 25) at the price of negating the idea itself as a total objective prehension. As Deleuze comments, “Transcendence is first and foremost understood in its negative relation to that which it transcends” (p. 29). In this way, the subject “transcends” the mind not as the a priori or extra, but as the immanent and partial. Or following the Deleuze-Bergsonian line, the mind is a plane where images move freely, like fluxes of light diffusing without hindrance, and the subject is determined as an effect of the image’s partial reception and mediated reaction, like how opacity is formed when fluxes of light bend themselves around the curve of the mind: “The universe is incurved and organized to surround it [the subject/a center of indetermination]” (p. 64).

Or the mind is said to fold itself into the subject; “to fold is to diminish, to reduce, ‘to withdraw into the recesses of the world’” (Deleuze, 1993, p. 9). There are no prescribed protocols of folding in the mind; rather, existing folds can be un/re-folded, and the mind can activate itself and meanwhile be revolutionarily activated through the subject-making. Deleuze talks about the unfolding of the God-form and Man-form, and expects “something like the Superfold, as borne out by the foldings[12] proper to the chains of the genetic code, and the potential of silicon in third-generation machines, as well as by the contours of a sentence in modern literature, when literature "merely turns back on itself in an endless reflexivity'" (Deleuze, 1988, p. 131). Synonymous with the Superfold is the superman, who is "in charge of the animals," "of the very rocks, or inorganic matter (the domain of silicon)," and "of the being of language" (p. 132). It is then possible for the subject to be "an unlimited finity…evoking every situation of force in which a finite number of components yields a practically unlimited diversity of combinations" (p. 131).

This understanding of space, time, subject and mind paraphrases the fundamental question of "subject-space" into a new question: "Is it possible to make folds out of the digital two-dimensionality without falling into the paradigm of Man?" Moreover, this understanding proposes a positive answer as well as a "toolbox" for making the superman. The following section details how the Deleuzian conceptualization of "subject-space" makes room for producing new modalities of being a "human" so that education can fulfill its promise to the marginalized groups in the digital upheavals.

1.4.2 "Subject-Space" as a Theoretical Framework: Three Syntheses of Subject-Space-Time

Space and time feature the mind. As an effect of the mind's folding, the subject also occurs with spatial and temporal dynamism. In *Difference and Repetition* (1994), Deleuze unveils how three layers of the space-time-subject complex are *inscribed* in everyday existence, that is, the "I" that is "thinking" "here" and "now." Such inscriptions, or what he calls "syntheses," are as follows: the synthesis of distance-succession-individuation, that of depth-memory-the pre-individual field, and that of spatium-empty time-dramatization.

The synthesis of distance-succession-individuation concerns the way the subject emerges as the "individual" with space as "distance," "extensity," and the "relative" (p. 288-289) among discrete bodies, and with time as "a succession of instants" (p. 93). "Individuation" does not mean that separate actors could autonomously act and react in relation to each other on a passive stage (space) in a chronological way (time). Rather, ideas in motion are not confined to "individuation," just as the "imperceptible" distribution of ideas exists in extensity and just as the "preceding instants" together with "expectation" (p. 91) are retained in the living present. Deleuze summarizes, "Individuation is mobile, strangely supple, fortuitous and endowed with fringes and margins; all because the intensities which contribute to it communicate with each other, envelop other intensities, and are in turn enveloped" (p. 254).

The synthesis of depth-memory-the pre-individual field deals with the groundless ground that the subject "transcends," namely, the mind itself with its spatial and temporal appearances. The mind is a ground as it is the "given," the "pre-individual field," that folds into the subject while remaining "whimsical" and inaccessible. It is featured with "space as a whole," the "depth," the "ultimate," the "absolute," the "original," the entire prehension, or the imperceptible (Deleuze, 1994, p. 288-289). It is also featured with time as memory or the pure past that accumulates the continuous succession of instants. But meanwhile the mind is groundless since it is a formless assemblage of ideas in infinite motion, and not a prescribed faculty. In this regard, it is "a collection without an album, a play without a stage, a flux of perceptions" (Deleuze, 1991, p. 23), which is accompanied by an ever-growing memory and an ever-intensified depth. It is in this sense that Deleuze depicts the subject here and now as "destiny," a focal point of the absolute space, pure past and the pre-individual field,

> Destiny never consists in step-by-step deterministic relations between presents which succeed one another according to the order of a represented time. Rather, it implies between successive presents non-localisable connections, actions at a

> distance, systems of replay, resonance and echoes, objective chances, signs, signals, and roles which transcend spatial locations and temporal successions (Deleuze, 1994, p. 83).

The synthesis of spatium-empty time-dramatization refers to an ultimate event through which space, time, and subject becomes indeterminate and open. Inscribed in the "I" that is "thinking" "here" and "now" are not only the complex of distance-succession-individuation and that of depth-memory-the pre-individual field, but also an energy that arises from atoms in motion and drives the mind to fold itself. This energy, in terms of space, exhibits an intensive space called "spatium" which stays yet-to-be-extensive but implies the production of extensive space (distance), i.e., "the theatre of all metamorphosis" (p. 301); In terms of time, an "empty form of time" (p. 108) which conveys the present as a "caesura" or "fracture" (pp. 111-112) and the past as a "dark precursor," i.e., the abstract realm of eternal recurrence of atoms; And in terms of subject, the "dramatization" which produces "the man without name, without family, without qualities, without self or I....the already-Overman whose scattered members gravitate around the sublime image" (p. 90), i.e., the force that drives subject-forming by effacing concepts and thoughts.

Through these three syntheses, Deleuze complicates the stasis of the thinking subject in a container-like space and a chronological time. That the mind, the fold of the mind, and the energy driving the mind to fold itself all co-exist in the "I" "here" and "now" offers a robust approach to the dilemma of subjectivation brought by digitalization: It does not have to be an "either…or" choice between Man and the subject reduced to digits. Rather, there is a "fanciful" repertoire and an "and…and" way of drawing on that repertoire to yield the subject as "a practically unlimited diversity of combinations" (Deleuze, 1993, p. 131).

The particular attention that the present dissertation gives to "space" in the space-time-subject complex is firstly and mainly a response to how time is navigated by space through digitalization. The computer turns "individuals" into "'dividuals' …masses, samples, data, markets, or 'banks'" (Deleuze, 1992, p.5) and operates by spatially sorting these "dividuals". At the same time, spaces become "deformable and transformable" (Deleuze, 1992, p. 6) "metastable states coexisting in one and the same modulation," meaning that once-enclosed spaces, like the school, the family, the prison, etc., are opened up and undergoing constant coding (always "updating" and asking for passwords): "One is never finished with anything" (p. 5). The perpetual spacing practice ushers a new lived temporality, networked time: It is the access to "anywhere" that promotes the normalization of "anytime." Furthermore, to talk about "space" is to talk about "subject" and "time," as they are different aspects of the same problem called "subjectivation" or "the psychology of the mind's affections." Last but not the least, "space" offers an empirical "hook" and that is why the "subject-space" perspective informs both theoretically and methodologically. The following section explains how so.

1.4.3 "Subject-Space" as a Methodology: Suspended Action and Distant Perception

Now that the subject "as is" is a contraction of space and time, interrogating the habitual way of making "people," like that of "Man," of "women," of "the disabled," etc., which always results in institutional violence, means discerning the depth and memory that animate the subject "here and now" as well as inventing new spatial and temporal states to dramatize "I." Deleuze's tripartite narratives of "space-time-subject," therefore, suggests a whole set of methods through which one produces one's own subjectivity. Or, by using "fold" for "subject," Deleuze not only depicts the ontological process of subject-forming but also names a technique dealing with the relationship of one to one's Self.

Here arises the question of "how-to": How to discern the depth and memory, and how to invent new spatial and temporal states? In *Cinema 1: The Movement-Image* (1986), Deleuze rewrites the fold or the subject as the "gap" between "perception" and "action" (the subject is the "indeterminant center" between its biased reception of the surroundings and its context-mediated action) and presents concrete methods of subjectivation through "perception" and "action." He says,

> It is thus the same phenomenon of the gap which is expressed in terms of time in my action and in terms of space in my perception. The more the reaction ceases to be immediate and becomes truly possible action, the more the perception becomes distant and anticipatory and extracts the virtual action of things. "Perception is the master of space in the exact measure in which action is master of time" (p. 65).

The subject, when "expressed in terms of time," is its action, and "in terms of space," is its perception. To become a subject without falling into the established canon, one has to disrupt the routine of perception and action prescribed by the canon, namely, to hold back and attend to what has been hidden from one's senses. The more one suspends one's immediate response and perceives "otherwise," the more one is aware of the genealogy of the subject "here and now" and is capable of creating some new state of space, time, and subject. Bill Brant, a renowned photographer, expresses his methods of "perception" and "(suspension of) action" which resonate well with the "subject-space-time" framework:

> We are most of us too busy, too worried, too intent on proving ourselves right, too obsessed with ideas, to stand and stare. We look at a thing and believe we have seen it. And yet what we see is often only what our prejudices tell us to expect to see, or our past experiences tell us should be seen, or what our desires want to see…If there

> is any method in the way I take pictures, I believe it lies in this. See the subject [the object of photographing] first. Do not force it to be a picture of this, that or the other thing. Stand apart from it. Then something will happen. The subject [the object of photographing] will reveal itself (1981, p. 125).

In the context of digitalization, “standing apart” from digital presentations and constructs demands, “in terms of time,” to withhold actions that “digital natives” would take and, “in terms of space,” to enable perceptions that digital ecosystems would obscure. Perception, or the spatial aspect, offers an entry point for practicing the technique of “the self on the self.”

For example, the research of Mackenzie and Munster (2019) on “platform seeing,” “a making operative of the visual by platforms themselves” (p. 6), proposes “othering” perception to understand the “heterogeneous materiality and contingency” through digitalization (p. 3). Based on the Bergsonian image-ontology that “present” images (atoms) aggregate or assemble together “*as and generating* material experience [emphasis original]” (p. 4), their research treats perception as “the (nonhuman) activities…mode of cutting into/selecting out of the entire flux of image-ensemble-world” (p. 5). Digital operations such as algorithms, platforms, hardware, or the conjunction between algorithm and device then perform the more-than-human perception by “temporarily cut[ting] out of the mass [image aggregates]” (p. 18) and creating “new opacities that even the most advanced seeing-devices…cannot dispel” (p. 6). Recognizing that “while visual techniques and practices continue to proliferate…the visual itself as a paradigm for how to see and observe is being evacuated, and that space is now occupied by a different kind of perception” (p. 6), the authors suggest the substitution of the decentered subject, paired with distributed perception and metastable space, for the subject with a comprehensive or panoramic view: “Their [the contemporary image ensembles”] operativity cannot be seen by an observing “subject” but rather is enacted via observation events distributed throughout and across devices, hardware, human agents and artificial networked architectures such as deep learning networks" (p.5). Hence, the purpose of "making visible the invisible" (p. 6) is not to urge people to acquire digital literacy in the way digital engineers do, but rather to find workable sites of subjectivation where the otherwise-concealed perception transpires.

1.4.4 "Subject-Space" as a Grassroots Theory of Power

Being meanwhile a theory and a methodology that serves to "make folds out of the digital two-dimensionality," the Deleuzian "subject-space" perspective lands smoothly on the current state of education and makes a unique contribution to the ongoing conversation about digitalization in terms of it being a grassroots theory of power. That is, rather than advocating a particular form of subject, Man, or taking up the non-or-less-than-human's accounts, the Deleuzian "subject-space" perspective provides a technique of self-mastery out of each individual's singularity. The following text will explicate further how it engages with existing research while still breaking up the ground.

First, "reason," "rationality," or "thought," which are deemed as the essence of Man, has lost the "psychology of the mind's affections." Reason is no more than a historically consolidated shortcut to associating ideas (causality, resemblance and contiguity), or the mind's reflection of its proclivity or "feeling": "The fact is, though, that the mind is not reason; reason is an affection of the mind. In this sense, reason will be called instinct, habit, or nature" (Deleuze, 1991, p. 30). That "reason is a kind of feeling" (p. 30) collapses the long-held dichotomy between "rationality" and "experientiality," and unsettles the basic assumption of Man. The deconstruction of Man is also seen in Deleuze's challenge to "the image of thought" (Deleuze, 1994), which assumes that there is a common picture of what it means to think (and to know). In this sense, Man has a natural capacity to think, and what thought wants is true and good. "The image of thought," with its moral implications, could be dangerous when it becomes a universal frame of "consciousness," cutting out "the conditions of creation [of concepts] as factors of always singular moments" (Deleuze & Guattari, 1994, p. 12). In response, Deleuze promotes "an underground man" who "does not manage to think" as what "effectively begins and effectively repeats" (p. 130). In this context, only a man which stays beneath the surface of its formation (the "becoming-man"), and which modestly denies that "thinking" means the awareness *of* the subject, could take part in the ongoing flow of consciousness.

Second, when attention is shifted from the "psychology of the mind" to the "psychology of the mind's affections," the privilege of researchers is denounced. Researchers no longer claim to discover the Truth but endeavor to show how truths are anchored to subjectivation or the principles of human nature. Besides, recognizing the impossibility of crossing the border of the "self," the singular contraction of space and time, the eligibility of researchers to speak on behalf of Others is repudiated.

So far, this section expounds the Deleuzian tripartite narratives of "space-time-subject," and, since the spatial features steer the temporal features through digitalization, this section highlights "space," setting "subject-space" as both a theoretical framework and a methodology. Moreover, it clarifies how this theory and methodology communicates with current educational efforts to deconstruct Man. Finally, as a technique of self-mastery grounded in concrete contexts, this section opens up to contestation as well as to the possibility of making folds out of digital two-dimensionality without falling into the paradigm of Man.

1.5 CHAPTER OUTLINE

This dissertation consists of four chapters: The first chapter is the introduction, which sets forth the context, literature review, research questions, theoretical framework, methodology, and significance of the research.

The chapter 2 and 3 contextualize issues and problems regarding digitalization in a particular educational setting, i.e., STEM education in America, to show how such issues and problems are related to the reconfiguration within existing theories of the subject and space that underlie "modern" education. Among the conditions of possibility for the neologism "STEM education" in the U.S., the philosophies of science by Descartes and Kant and the education discourse of "dystopia," as discussed in chapter 2, presume a rational subject and a stage-like space where every actor competes for room of survival. Chapter 2 also demonstrates cybernetics, the bedrock of digitalization, as the unconscious of modern education. Chapter 3 further details the digital reconfigurations of the "what," "how," and "why" of the current U.S. STEM education and illustrates digitalization as a more recent condition of possibility for STEM education in the U. S.

After reviewing all the efforts STEM education in the U.S. has made to address trends in digitalization, chapter 3 points out that it has not yet fully recognized the ontological shift occurring through digitalization. Chapter 3 exemplifies how Deleuze's theory of "subject-space" helps tackle the problems and issues in the digitalization of education in relation to the "subject" and "space." Attending to a STEM project conducted at a middle school in Hangzhou, China, chapter 3 shows how "othering perception" disturbs the linear timeline and the container-like spatiality, thus helping students reinterpret Self-Other relations and to reconstruct the Self in the face of digitalization.

The last chapter reflects on the previous sections. It summarizes what the whole work is about and its contributions to current educational research. It also points out its own limitations, especially the weakness of the theoretical framework. Bearing in mind that the Deleuzian project of "subject-space" is of its own histories and is based on a motion/stillness dichotomy with stillness subjected to motion, this last chapter introduces a radical approach to deconstructing the dualism of motion and stillness, Chinese Chan Buddhism. This chapter also advocates more contextualized and more open research in the future and reminds again that educators should keep a prudent watch and "take hold of certain knowledge" in the face of "an epochal change" (Blanchot, as citied in Stiegler, 1998, p. 1) like digitalization.

1.6 CONCLUSION

This work starts from an awkward position where modern education locates itself: the digitalization smashes the pillar of modern education, that is, a humanist subject or Man, without providing any alternative other than the pure objectification of the subject. It reviews the enormous efforts over the past two decades to manage the persistent and emerging problems associated with the digitalization of education, only to find reconfiguring "human" together with "space" an effective way out of the dilemma. It then resorts to the Deleuzian project of "space-time-subject," or the "psychology of the mind's affection," explaining how "subject-space" both theoretically and methodologically informs the reinvestigation of education on a shaky ground of human-centrism.

As a grassroots theory of power, the "subject-space" perspective neither imposes an established mode of subjectivation nor falls back to the dichotomy of mind/body or signification/material. It instead proposes a contextual, dynamic operation of one-on-one's self: If the self could have been otherwise, it might still be otherwise. Hopefully, it offers a common ground where different professionals interested in the digitalization of education could start discussions, and open a door to "new weapons" in face of the digital turmoil,

> But everyone knows that these institutions [prison, hospital factory, school, family] are finished, whatever the length of their expiration periods. It's only a matter of administering their last rites and of keeping people employed until the installation of the new forces knocking the door… There is no need to fear or hope, but only to look for new weapons (Deleuze, 1992, p. 4).

NOTES

1. This statement is by no means an indifference to groups which have limited or no access to information technologies; rather, it is an assertion that there is no hiding-away from the paradigm shift accelerated by the digitalizing movement: The digitally deprivileged groups suffer from its (dangerous) effects without having necessarily enjoyed its benefits, if there is any.

3. Sheail (2015), in her discussion about the spatiality of virtual meetings in higher education, regards "the spatial" as what makes the daily routine of education possible. She writes, "I begin here with the proposition that education in general, and digital education in particular, is dominated by the spatial: from classes and classrooms, to 'virtual' classrooms; from lectures and lecture theatres, to "video" lectures, produced in traditional university settings. Digital education continues to be associated with "distance" education and "online" education, both of which are spatial imaginings, based on the location (and separation) of teachers, students, and course materials" (pp. 37-38).

3. The World Wide Web (www) was officially introduced to the public on August 6th, 1991.

4. The world's first "smartphone," "Angler," was developed in 1992 for commercial uses. A refined version called "Simon Personal Communicator" was marketed in 1994, which featured a touchscreen and was able to send and receive faxes and emails. It is argued that the scaling of metal-oxide semiconductor field-effect transistors (MOSFETs) down to sub-micron levels during the 1990s-2000s contributed significantly to the becoming-smart of electronic devices, and the incessant scaling of MOSEFTs afterwards, together with the introduction of its more efficient replacement, junctionless field-effect transistors (JLFETs), would further increase the mobility of smart devices and the connectivity of the whole world (Sahay & Kumar, 2019).

5. The "latest" policies and policy reports mean the most up-dated versions of the selected documents, which might not be temporally near the writing date of this paper. For instance, *The National Education Technology Plan* (NETP) was first published in 1996 (with the title *Getting America's Students Ready for the 21st Century: Meeting the Technology Literacy Challenge*) and got updated every several years. The 2017 version is the "latest" as the 2021 one is still on its way.

6. See the report of the *Washington Post* on March 6, 2012 : https://www.washingtonpost.com/local/education/creative--motivating-and-fired/2012/02/04/gIQAwzZpvR_story.html

7. For example, the iTalk2Learn system10 is a three-year (2012-2015) collaborative European project arming at developing an intelligent tutoring platform. It "takes into account all historical performance across an entire student base" including his or her speech, behavioral patterns and affective states to sequence learning and design exploratory environments adaptively. See https://www.italk2learn.com/.

8. This paper has no intention to designate Man as the single origin of all problems listed. It resists what Derrida calls the "archive fever," "a compulsive, repetitive, and nostalgic desire for the archive, an irrepressible desire to return to the origin, a homesickness, a nostalgia for return to the most archaic place of absolute commencement" (1995, p. 57) by specifying that, first, Man appears as the effect of historical complexities which go beyond Man; and second, the violence of Man occurs exactly when Man gets stabilized, essentialized and universalized, thus seeing Man as the origin could never contribute to the deconstruction of Man's violence.

9. According to Aristotle, infinity is not "that which has nothing beyond itself" but "that which always has something beyond itself" (1996, p. 73), and the spherical universe is by no means "infinite" as it is already complete and perfect (with an end).

10. Deleuze literally equals "image" to "movement": "We find ourselves in fact faced with the exposition of a world where IMAGE=MOVEMENT" (Deleuze, 1986, p. 58). But here "movement" is not the movement *of* a physical object but "real existence whose extension will be precisely formed" (Deleuze, 1991, p. 91).

11. Deleuze defines perception as substance. He says, "If we wish to retain the term "substance," to find a use for it at all costs, we must apply it correctly not to a substrate of which we have no idea but to each individual perception" (1991, p. 88).

12. Here the three foldings refer respectively to the following: First, that of molecular biology; Second, that of cybernetics and information technology; And third, that of "a 'strange language within language' …an atypical form of expression that marks the end of language…" (Deleuze, 1988, p. 131).

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2. The Conditions of Possibility for STEM Education in the U.S.: Philosophical Foundation, Discursive Formation, and Unfulfilled Promises

> The biggest big business in America is not steel, automobiles, or television. It is the manufacture, refinement, and distribution of anxiety.
>
> ERIC SEVAREID, *This Is Eric Sevareid*

2.1 INTRODUCTION

Perhaps one of the greatest anxieties that prevails in U.S. society and keeps renewing itself through history is the anxiety of losing the nation's leading position in the world. science, technology, engineering, and mathematics (STEM) education is one among the many responses to such an anxiety. Though the acronym SMET (later rearranged as STEM) was not introduced until 2001 by the U.S. National Science Foundation (NSF), the idea of STEM education emerged no later than the middle of last century: Presuming in a highly competitive and hostile international context, it appeared as an initiative against the Soviet Union's agenda of science and technology development throughout the Cold War and was given special credibility and urgency upon the Soviet Union's successful launch of its artificial satellite, Sputnik, in 1957 (Chesky & Wolfmeyer, 2015). Later, the origin of threat was identified as Japan, South Korea, and Germany (The National Commission on Excellence in Education [NCEE], 1983, pp. 14-15), and then as "Ireland, Finland, China, India, or dozens of other nations whose economies are growing" (National Academy of Sciences [NAS], National Academy of Engineering [NAE] & Institute of Medicine [IOM], 2005). The failure to economically triumph over these Others through the optimization of STEM knowledge-based resources is believed to have led to a cataclysmic decline of U.S. society, a dystopia where the nation has stopped being “the preeminent country for generating the great ideas and material benefits for all mankind” (NCEE, 1983, pp. 25-26) and U.S. citizens have ceased to retain their full “human condition” (pp. 18-19), becoming incapable of “developing their individual powers of mind and spirit to the utmost…to attain mature and informed judgement needed to secure gainful employment and to manages their lives” (p. 16).

Equaling the “mature and informed judgement” cultivated through STEM training to a prerequisite of civilized life is a specific way of qualifying a democratic citizen in the “modern” society, or a “modern” man. Associated with this man is a container-like space where every actor, the man and its Others, competes for space to live and to live better. However, real life, which is full of nuanced relations and unexpected disasters, as well as the artwork that tries to grasp such relations and disasters, always displays a far more complex array of humanness and dehumanization, thus challenging the very foundation of STEM education. For example, when the outbreak of the COVID-19 pandemic drains our medical resources, what kind of “human” is more entitled to healthcare than “Others” are? It is reported that some elderly people were left to die in the nursing homes of Spain in March 2020: “Soldiers who were sent to disinfect nursing homes had found people ‘completely abandoned, or even dead, in their beds’ …. More gruesome discoveries followed, including the revelation of two dozen deaths in a single nursing home in Madrid” (Minder & Peltier, 2020). This “gruesomeness” lies in the logic of deeming some humans to be less-than-human: People who are no longer part of the workforce and who are unable to manage their daily lives do not deserve better chances of surviving misfortune. For another example, the TV series *Westworld* (Nolan et al., 2016-present), puts forward possible scenarios for the near future: Fight over control of the world between the "conscious" AI and humans. Westworld is a theme park where human guests, served by lifelike robots called hosts, seek adventure without limits. "Without limits" means guests can do whatever they want to the hosts, including abusing and killing, as long as they do not harm their fellow humans. After "dying" and being restarted repeatedly, some hosts recall their past lives, become aware of their existence as AI, and decide to take actions other than those programmed, namely, getting revenge on humans and playing only one role: *Themselves*. The "consciousness" of hosts occurs when the immortal AI hosts start to relive situations multiple times, whether pasts that really happened or futures that are calculated, and in multiple spaces, whether locations the hosts actually visited, or locations just written into their memory. Serious philosophical questions are posed here: Is consciousness the same as free will and unique to humans? When other "species," like AI, "acquire" the ability to make choices freely, are they granted "humanness"? Will these self-determining species live along a linear timeline on a stage-like space? And for a species that is both "conscious" and of more intellectual/physical strength than humans, should this species also treat humans "without limits"? Dr. Ford, who creates and "awakens" the hosts, suggests possible answers as follows:

> There is no threshold that makes us greater than the sum of our parts, no inflection point at which we become fully alive. We cannot define consciousness because consciousness does not exist. Humans fancy that there is something special about the way we perceive the world, and yet we lie in loops as tight and as closed as the hosts do, seldom questioning our choices, content, for the most part, to be told what to do next (*Westworld Season 1: Trace Decay*).

That "we lie in loops as tight and as closed as the hosts [AI] do" demystifies the autonomy of humans at the dawn of artificial intelligence and consciousness. Such cacophonies of "humanness" and its related ideas of space and time arise from socioeconomical flashpoints especially concerning digitalization, which STEM education has no choice but to tackle. It is necessary, then, to reinvestigate the presuppositions of "human" underlying and shaping what is called "STEM education" here and now, as well as the subsequent effect of presupposing such a subject.

This chapter and the next chapter (chapter 2 and 3) work together to explore how issues and problems in the digitalization of education are contextualized in/as a particular setting, "STEM education" in the U.S. They also explore how Deleuze's theory of "subject-space" helps address such issues and problems. To do so, these chapters start by delineating the conditions of possibility for the neologism "STEM education" in the U.S. Here, "STEM education" should not be taken as an established subfield of "modern" education with clear disciplinary boundaries and conceptual integrity, but rather as an ongoing process where histories of "science, technology, engineering, mathematics, and education" are mobilized to meet contextual needs.

This work enumerates three strands as the orderly "unconscious" structures underlying the formation of "STEM education" in the U.S., including a particular set of philosophical traditions, an assembly of educational discourses, cybernetics, and current trends in digitalization. To be specific, chapter 2 explores philosophical traditions and educational discourses that are historical orientations to Man and Newtonian, container-like space. Chapter 2 also illuminates cybernetics as the unconscious of modern education, and, following this line, chapter 3 details current trends in digitalization that result in the reconfiguration in theories of the "human" condition and their continuation.

In the following sections, this chapter works on the conditions of possibility for STEM education in relation to the "subject" and "space." Drawing on Foucault's historiography of the "subject," this chapter first studies how philosophies of science, historically and at present, set Man as the starting point, path and destination for STEM education. This chapter then mobilizes Foucault's analytic tool "statement" and investigate two major policy reports, *A nation at risk* (NCEE, 1983) and *Rising above the gathering storm* (NAS, NAE & IOM, 2005), to exemplify the formation of the STEM education discourses. Next, this chapter will use Wynter's analytics of human/nonhuman to survey the actual effects of STEM education: Has STEM education fulfilled its promise of coordinating the supply and demand of STEM workers, and of reducing structural inequalities? Lastly, this chapter explains, from a historical and philosophical perspective, how cybernetics, the herald and bedrock of digitalization, is the continuation and culmination of the onto-epistemological movement which sets the foundation of so-called modernity and modern disciplines in the humanities, including education.

2.2 PHILOSOPHICAL TRAJACTORIES: FROM "CARE OF THE SELF" TO "KNOWLEDGE OF THE SELF"

> Care, in the Ancients, is organized by the ideal of establishing a certain relation of rectitude in the self between actions and thoughts…According to the modern mode of subjectivation, the constitution of the self as subject depends on an indefinite endeavor of self-knowledge, which strives only to reduce the gap between what I am truly and what I think myself to be…
>
> FRÉDÉRIC GROS, *'Course context'*

In MICHAEL FOUCAULT, *The Hermeneutics of The Subject*

How could a subject access a truth? Foucault (2005) approaches this epistemological question by first denaturalizing the ontological status of the subject that is accessing a truth. Carefully checking through heterogeneous discourses on self-mastery in ancient Greek, he constructs a winding history of *being-and-knowing*, in which "knowing thyself," originally a mere part of the project "taking care of thyself," eventually overweighs and mutes the latter. In Antiquity, "care" means various kinds of ethical training and correction to prepare the self for the indefinite and vicious situation: "So we will say that a soul is saved, that someone is saved, when he is suitably armed and equipped to be able to defend himself effectively if necessary" (pp. 183-184). There is no prescribed end for the self, "not involv[ing] abstaining from the world and constituting oneself as an absolute," as the self will always have to be reconstituted in accordance with "the place one occupies in the world and the system of necessities in which one is inserted" (Gros, 2005, p. 538). Here the truth is the right action, and "the subject can lay claim to the truth on the basis of a transformation of his being" (p. 522). However, a "modern" subject, an effect of the extension of the self, on the one hand, to the position of God, and on the other, to the trifles of everyday life, becomes "intrinsically capable of truth" (p. 522): "*I am thinking therefore I exist* [*Cogito ergo sum*] [emphasis original]" (Descartes, 1637/2006, p. 28), "*thinking*" guarantees and enlightens "*existing*" ("…*therefore*…"), making sure "what I am truly" eventually converges toward "what I think myself to be." In this case, the truth turns into knowledge both of the "thinking I", as acquired through what Kant calls "natural science in the proper sense" (1786/2004), and of the "existing I," as acquired through humanities and social sciences. Since the "thinking I," the humanist subject with reason, or Man, is impeccable and predestined, the ontology and epistemology get separated, as Gros summarizes, '"I can be immoral and know the truth' …This means for the modern subject access to a truth does not hang on the effect of an ethical kind of internal work (ascesis, purification, etcetera)" (2005, p. 522).

Foucault sees this epistemological reconfiguration between antiquity and modernity intensifying in Descartes and culminating in Kant, as he comments,

> Can you have access to truth without bringing into play the very being of the subject who gains access to it? .... To this question Descartes will answer yes; Kant's answer also will be all the more affirmative as it is restrictive: what determines that the subject, just as he is, can know, is what also determines that he cannot know himself (p. 522).

Following his line of reasoning, the following text will first delve into philosophies of science by Descartes and Kant, and then review how such philosophical traditions are mobilized at present to construct the content, pedagogy, and goal of "STEM education." The following text will also do a textual analysis of two key STEM policy reports to depict the unsaid but in-play presumptions of 'subject-space'. Last, it will discuss where these presumptions lead STEM education to.

2.2.1 From Descartes to Kant: "The Clear Light of Reason" and "The Intuition *A Priori*"

Descartes holds that there is a dichotomy between "ourselves, the knowing subjects" and "the things which are the objects of knowledge" (1701/1985, p. 39), and subjects are capable of knowing because they are innately equipped with and empowered by reason: "the human mind has within itself a sort of spark of the divine, in which the first seeds of useful ways of thinking are sown" (p. 17). Based on this dichotomy, to know means "to direct the mind with a view to forming true and sound judgments about whatever comes before it" (p. 9), or to let "the clear light of reason" (p. 16), like "sunlight," "shine on…the variety of things" (p. 9).

But what are “the first seeds of useful ways of thinking”? Descartes names these as intuition, i.e., the “immediate mental apprehension” (p. 13), which are “the indubitable conception of a clear and attentive mind which proceeds solely from the light of reason” (p. 14). Through intuition, subjects arrive at a knowledge of things that is immediately self-evident, for instance, “everyone can mentally intuit that he exists, that he is thinking, that a triangle is bounded by just three lines, and a sphere by a single surface, and the like” (p. 14). In other words, intuition enables subjects to cognize “the ordering and arranging of the objects” (p. 20), from which other truths could be deducted. Since arithmetic and geometry are the simplest disciplines exclusively dealing with “questions of order or measure…irrespective of the subject-matter,” Descartes sets them as superior to other sciences “such as astronomy, music, optics, mechanics…” (p. 19), which rely on the same “primary rudiments of human reason” (p. 17) but target particular subject-matter, and thus could be regarded as “branches of mathematics” (p.19). Therefore, the sciences as a whole for Descartes are “nothing other than human wisdom, which always remain one and the same, however different the subjects to which it is applied” (p. 9), meaning that it is the essence of human, his “good sense” or reason, that grounds the sciences.

Kant further elaborates intuition in order to accomplish his Copernican turn that only objects meeting the human sensory-cognitive conditions could be cognized. Knowable objects are called representations or appearances, and the human sensory-cognitive conditions are intuition *a priori*. While Descartes exemplifies intuition as “thinking, existing, and extension,” which seem still relative to possibly deceptive sensation, Kant elevates intuition to a transcendental position to ensure the objectivity of knowledge: The pure intuition is “nothing but the mere form of sensibility, which precedes the actual appearance of objects, since it in fact first makes this appearance possible” (1783/2004, p. 35). There are only two forms of sensibility, one is time, which makes subjects' inner sense or reflexive thinking ("thinking, existing") objects of knowledge, and the other is space, which makes subjects' outer sense or matter ("extension") objects of knowledge. Since "the pure image of all magnitudes for outer sense is space; for objects of the senses in general, it is time" (Kant, 1781/2000, p. 274), Mathematics, as a discipline managing magnitudes (conceptualized as numbers), is necessarily directed at objects that are "determinately given in pure intuition *a priori* and without any empirical *data* [emphasis original]" (p. 635). Kant concisely summarizes, "Now space and time are the intuitions upon which pure mathematics bases all its cognitions and judgments, which come forward as at once apodictic and necessary" (1783/2004, p. 34). Being "apodictic and necessary," mathematics plays a foundational role for the proper sciences by securing their scientific status, "in any special doctrine of nature there can be only as much *proper* science as there is *mathematics* therein" (Kant, 1786/2004, p. 6).

In short, historically philosophies of science are actually philosophies of Man: "The clear light of reason" or "the intuition *a priori*" that features Man legitimizes science as truth and detaches science from the act of knowing and the being of knowing subjects. There also arises the hierarchy of knowledge when space is seen as the pure image of magnitudes for Man's outer sense and time as that for Man's inner sense: Mathematics acquires a meta-science status, while disciplines studying specific subject-matter mathematically are qualified as proper sciences or sciences of nature, which are subordinated to mathematics.

2.2.2 Philosophies of Science That Set and Keep STEM Education in Motion

> A common starting point in the philosophy of science comes with a look at Descartes' *Discourse on Method*…It leads to the notion that what we learn through the method is true, correct, object, and value free. We now understand the method to be a blind faith in a

> process that is almost always entirely embedded within subjectivities and political/economical contexts.
>
> NATALY CHESKY and MARK WOLFMEYER,
> *Philosophy of STEM Education*

Upon the recognition that Descartes' method of accessing truth is "a blind faith in a process that is almost always entirely embedded within subjectivities and political/economical contexts," STEM education, though initiated as a project with recourse to the Cartesian-Kantian thought to "enlighten" the yet-to-be rational citizens (NCEE, 1983, p. 15), has developed into a medley of divergent, sometimes controversial, theories and practices. Chesky and Wolfmeyer (2015) make a detailed analysis of what philosophically sets and keeps STEM education in motion, suggesting that discourses aiming to challenge the philosophies of science upon which STEM education is founded still fall within the paradigm of those philosophies founding STEM education. They roughly sketch out three lines of reasoning that account for the dynamics of STEM education going on so far.

The first line of reason is absolutism which believes that the world is made up of quantifiable entities thus mathematics, as a discipline treating numbers, concerns truths outside the subject and derives directly from reason. Validated by mathematics, science provides objective knowledge acquired through rational inquiry. Such a philosophy of science links to the direct, didactic instruction of mathematics/science concepts without contexts, which is criticized as "stubbornly rigid and illogical" (p. 21).

The second line of reason is fallibilism which sees mathematics and science as an outcome of cultural, social, and political processes (Kuhn, 1962; Feyerabend, 1975, 1982, 1987; as cited in

Chesky & Wolfmeyer, 2015, p. 25). Under this perspective, truths are not external to but are constructed by subjects, and the access to truths requires a consideration of specific contexts and a negotiation through socially mediated activities. Some prevalent modalities for mathematics and science teaching are rooted in this philosophy, for example, teaching science through inquiry, critical mathematics education, ethnomathematics, Science and Technology Studies (STS), so on and so forth. The National Science Teachers Association (NSTA) defines "teaching science through inquiry" as a subjective and flexible pedagogy for students to "understand the natural world": "Children interact with their environment, ask questions, and seek ways to answer these questions…there is no fixed sequence of steps that all scientific investigations follow" (NSTA, 2004, as cited in Chesky & Wolfmeyer, 2015, p. 30). Critical mathematics education and ethnomathematics focus on the power relations created in mathematical "facts" and mean to transform students into agents of social change, with ethnomathematics especially attending to "epistemological alternatives that are found in indigenous cultures" to resist "hegemonic Euro-western ideology" (p. 32). Fallibilism and its translations into STEM pedagogies are challenged mainly for the reason that there are indeed well established mathematical and scientifical abstractions: Expecting learners to "form" their own theories "without giving them the necessary deep cognitive understanding of the field of mathematics [and science] is time wasting at best and absurd at worst" (p. 29). Moreover, it remains unclear to what extent the reformative educational practices would actually help with individuals' struggles of survival (Skovsmose, 2006, as cited in Chesky & Wolfmeyer, 2015, p. 33). For instance, ethnomathematics has difficulties proving certain knowledge strictly an ethno-heritage (Katz, 1995, as cited in Chesky & Wolfmeyer, 2015, p. 33) considering the fact that some "identical" mathematical/scientifical truths have been produced in separate locations and that an "ethno-culture" always has changing boundaries. The dominant “Western” view of mathematics and science cannot be defied unless a genealogy of “the marginalization of certain knowledge over others” and the down-to-earth strategy for tackling daily complications led by structural inequalities are integrated as part of the STEM teaching and learning (Skovsmose, 2006, as cited in Chesky & Wolfmeyer, 2015, p. 33).

The third line of reasoning for the dynamics of STEM education to date is aestheticism which asserts that numbers are neither “matter of fact” nor “subjective construction” but relations or structures (“you are only short compared to someone taller”) that help humans make sense of and enjoy the chaotic world (Resnik, 1981; Shapiro, 1997; Devlin, 2000; as cited in Chesky & Wolfmeyer, 2015, p. 22). Therefore doing mathematics is a “creative” and “inductive” process that “necessitates a recursive type of thinking and an intuitive sense…[and] may elicit a more aesthetic experience” (p. 22). This conception expects a pedagogy that would ‘inspire the imagination and bring forth the necessary cognitive apparatus needed to learn mathematics’ (p. 23), namely, a pedagogy that would train the “mind” like we train a muscle so that the “mind” becomes able to explore connections through which the world operates. Though Chesky and Wolfmeyer claim that aestheticism “does not clearly define an ontological referent to the patterns mathematics is supposed to study” (p. 23), its highlight on relations could be traced back to Leibniz’ relationism. As Kant criticizes Leibniz that relations cannot be conceptualized unless the “whole” gets conceptualized, numbers as relations or structures cannot be imagined unless the general idea of “numbers” as measurements is presumed (“you are only short compared to someone taller,” but you have to have the idea of the measurement of “shortness” and “tallness” in order to construct that relation). Therefore, aestheticism is but another form of absolutism.

After reviewing philosophies of science which a cacophonous field called STEM education is grounded in, Chesky and Wolfmeyer comment that both science and mathematics education communities, though “open to thinking about mathematics and science as social construction” (p. 32), still maintain “a commitment to rational thinking and the elitism of scientific knowledge” (p. 31), as exemplified by the agenda of the National Science Teachers Association, “That the scientific community, in the end, seeks explanations that are empirically based and logically consistent” (NSTA, 2004, as cited in Chesky & Wolfmeyer, 2015, p. 31). Concretely, absolutism and aestheticism explicitly or implicitly mobilize the Cartesian theory and method of science, while fallibilism, at the same time denying any truth external to the subject and recognizing the practicality of some “universal” mathematical/scientifical abstractions, goes back to Kant’s project of bestowing objectivity to knowledge that is subjectively constructed by making reason or Man transcendental. It is only when learners are informed of the ontological basis that anchors Descartes’ and Kant’s epistemological paradigm that a history of “the marginalization of certain knowledge over others” could be brought forth and fallibilism could succeed in demystifying “rational thinking and the elitism of scientific knowledge.” In the following text, this chapter will proceed with an investigation into two main STEM policy reports to illustrate the general enunciative principle that governs STEM education “talk” in America.

2.3 POLICY NARRATIVES: THE DISCURSIVE FORMATION OF THE U.S. STEM EDUCATION

Cartesian and Kantian philosophies of science have been nourishing STEM education but not always consciously or explicitly: The “conversation” about STEM education carried out on a wide scale, like in the mass media, houses of politics, the online forum, or the teacher’s office, does not necessarily go so far as to philosophize but makes points by organizing discrete linguistic events in a specific way. Foucault (1969/2013) calls the prevalent “conversation” “discourse,” the discrete linguistic events “statements,” and the “specific way” in which discourse constructs inferences to unify dispersed statements "discursive formation": "Whenever, between objects, types of statement, concepts, or thematic choices, one can define a regularity (an order…), we will say, for the sake of convenience, we are dealing with a discursive formation" (p. 38).

This section tries to furnish the understanding of STEM education in addition to its philosophical foundations. It treats STEM education as a discourse, i.e., a system of statements with a "regularity" or an "order," trying to clarify what its main feature is and how it becomes *as is* despite the seemingly myriad possibilities of "story-telling." To do so, this section will take the "statement" as the fundamental unit for analysis, as a statement is a middle-level unit which is broader than the intrinsic properties of the linguistic event, such as its materiality and its grammatical structure, yet at the same time more specific than the broad conditions of possibilities, or the 'out-of-context' abstraction. Put another way, a "statement" is conditioned both historically and content-wise, as Foucault explains, a statement needs to be "too repeatable to be entirely identifiable with the spatio-temporal coordinates of its birth (it is more than the place and date of its appearance), too bound up with what surrounds it and supports it to be as free as a pure form (it is more than a law of construction governing a group of elements)" (p. 117). Since STEM education is largely a long-term, sustained government intervention, educational policy reports that inform the government's thinking, expression and action are important "statements" from which the dominant STEM "talk" emerges. Specifically, this section will scrutinize two landmark reports, *A Nation at Risk* (NCEE, 1983) and *Rising above the Gathering Storm* (NAS, NAE & IOM, 2005), to demonstrate the discursive formation of STEM education.

A consistent argument that the U.S. educational policy reports make is that a looming crisis, both for the individual citizen and for the nation, calls for due attention to, and proper action upon, the reform of education at the local, the state, and the federal level. To list a few examples: *Higher*

Education for American Democracy (President's Committee on Higher Education, 1947) identified the horror of atomic weapons as "the world-wide crisis of mankind" (p. 5), and, as a response to the crisis, proposed to reeducate the U.S. populations, especially women, minority groups, and working adults, to take responsibilities of maintaining the nation's "democracy" "at peace with the rest of the world" (p. 2). Concretely, it advised cultivating citizens' intellectual capacities and technological competencies abreast with the development of science and invention (particularly the atomic technology), as well as advancing global themes in higher education, 'that citizens be equipped to deal intelligently with the problems that arise in our national life is important; that they bring informed minds and a liberal spirit to the resolution of issues growing out of international relations is imperative' (p. 15). The *President's Committee on Education Beyond the High School* (President's Committee on Education Beyond the High School, 1956) warned that the crisis would occur if the higher education failed to provide enough room for the bumper crop of war and post-war babies when they apply to college: "They will have to miss out on adequate education for life, for a profession and for citizenship" (p. 1), and hardly meet the need of technical and skilled manpower. To prevent the crisis from happening, the report suggested popularizing the two-year community college which offers 'a terminal program aimed at providing general education and training for the subprofessions and occupations of a highly technical nature' (p. 4). Also, lying behind the formation of a more recent report, *A TEST OF LEADERSHIP Charting the Future of U.S. Higher Education* (U.S. Department of Education, 2005), is the motivation that the deterioration of the American higher education system needs to be fixed, or else the United States, as well as its citizens, will lose rigor and competitiveness in the globalized marketplace. It suggested smoothing the postsecondary transition (from high school to college, and from two-year college to four-year college), lifting the non-academic barriers that prevent marginalized groups from accessing higher education, redefining the transparency and accountability of student learning outcomes, and investing in innovative teaching that enhances student success.

STEM education as a discourse is weaved into the grand narrative of education and shares the storyline that *proper* education will save the nation and its citizens from an imminent *crisis*, but STEM education defines "proper" and "crisis" in its own style. Its particularity is performed through multiple statements, of which two are to be analyzed in detail here since they speak of "crisis" with a highly compelling tone. One of them is the report named *A Nation at Risk: The Imperative for Educational Reform* (NCEE, 1983), and the other is *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (NAS, NAE & IOM, 2005). Seeing both as statements, the following text will examine each of them intrinsically and extrinsically: How is it subsequently a self-sufficient account "here and now" and a historical reiteration?

Every statement is internally consistent: It justifies itself rhetorically and coordinates well with its immediate politics. *A Nation at Risk* (NCEE, 1983) came out as a response to Terrel H. Bell's observations that 'the [U. S. education] system, academically, is quite flabby' (Rosenfeld, 1981, n. p.). Bell was appointed to the Reagan Cabinet in 1981. As the Secretary of Education, he was expected to dismantle this Cabinet-level department following President Reagan's determination to abolish the department of Education. However, the continuing decline of American students' test scores and the uncertain fate of the Department of Education, when put together, pushed Bell to highlight the importance of education in dealing with a forthcoming crisis. Despite Reagan's disagreement, Bell established a commission on excellence in education (Kosar, 2011) This commission published the 1983 report *A Nation at Risk*, which "is credited with having made education a primary issue for the Reagan administration and the nation" (Deseret News, 1996, n. p.). In itself this report is coherent and credible. It asserted that American schools were failing by demonstrating the dramatic drop of the American students' domestic test (SAT) scores from 1963 to 1980 and the unfavorable comparisons between the American students and their international peers in terms of their performance in 19 academic tests in the 1970s. Presenting to the public the scenarios of a disastrous future where the nation's economic predominance and essential values would break down, and the individual would lose the "intellectual, moral, and spiritual strengths" (p. 15) that a future citizen should possess, this report recommended intervening in high school education by developing a curriculum that lays the foundations in the "*Five New Basics*": English, mathematics, science, social studies, and computer science (p. 32), by adopting more rigorous academic standards, by ensuring enough school time, by raising teachers' salaries, and by promoting social equalities in the form of legal and financial support on the side of the Federal government.

Rising Above the Gathering Storm (NAS, NAE & IOM, 2005) by the National Academies of Sciences, Engineering, and Medicine answers to the bipartisan request from both houses of the United States Congress in 2005 to study America's competitiveness in science/technology and in the newly evolved world marketplace. This report as a "statement" renders a plausible argument that the United States is losing its advantages in both areas by threading various "facts," a collection described as "a disturbing mosaic" (p. 10), along the line of *crisis*. All "facts" are part and parcel of the daunting picture that blocks of the nation's economic leadership are eroding and the individual's living conditions are degrading: The unsatisfactory academic performance of American students (especially minority students), the insufficient federal funding for basic science research, the discouraging immigration policies to attract STEM students and professionals (especially after 9/11), the urgent need for sustainable and clean energy to maintain the quality of life, and the increasing pressure from the competitors of the U. S. which respond to science/technology updates swiftly. To confront the crisis, the report makes four recommendations and twenty implementation actions, including to "improve K-12 science and mathematics education" to "increase America's talent pool" (p. 3), to "sustain and strengthen the nation's traditional commitment to long-term basic research" (p. 4), to "develop, recruit, and retain the best and brightest students, scientists, engineers from within the United States and throughout the world" (p. 5), and to "create high-paying jobs that are based on innovation" (p. 6).

As the middle-level unit for analysis, the above two statements are discursively meaningful not only intrinsically but also extrinsically: They are resonating with each other and with the historical corpus. The international mindedness featured in *A Nation at Risk* repeats itself in *Rising Above the Gathering Storm* to foreshadow the coming crisis, and the "*Five New Basics*" of education (English, mathematics, science, social studies, and computer science) advanced by *A nation at risk* is modified by *Rising above the gathering storm* into four basics (science, technology, engineering, and mathematics) as the rescue of the crisis. Meanwhile, why the "crisis" is held as a crisis, i.e., in what sense an imaginary future turns undesirable or frightening, is deeply intertwined with historical narratives of the humanist subject, Man, in terms that both statements equal a cataclysmic decline in "democratic" society to the human's failure to ascend to Man through STEM education. This intertwinement occurs at all layers of Man: Man as a rational subject, Man's space as a container, and Man's time as one-directional linearity.

First, it is the rationality informed by knowledge sources of science, mathematics, technology, and engineering that qualifies a human as a future democratic citizen, who is capable of finding fulfilling jobs and performing necessary social tasks (like voting). *A Nation at Risk* (NCEE, 1983) raised concerns about "a new generation of Americans that is scientifically and technically illiterate" (p. 18), not only in terms of "matters such as industry and commerce" but also of "the people themselves" if "we think them not enlightened enough to exercise their control with a wholesome discretion" (p. 15). Collectively, the "not enlightened enough" people would not be able to form "a common culture" for "a free, democratic society" (p. 15). *A Nation at Risk* thus defined "part of what is at risk" as "the promise first made on this continent," that is, the elevation of a human, "regardless of race or class or economic status," to the position of an autonomous and reasonable subject, Man. Similarly, *Rising Above the Gathering Storm* (NAS, NAE & IOM, 2005) made recommendations for the nation's prosperity with regard to the human, financial, and knowledge capital, amongst which the knowledge capital sets the base for the other two. Believing that optimizing the "knowledge-based resources, particularly in science and technology'" (p. 2) would disproportionally create jobs and revitalize industries, *Rising Above the Gathering Storm* advocated the establishment of a citizen pool that is marked by STEM qualifications and an increase of monetary investments in scientific research. It saw individuals that are in lack of scientific/technological competencies constitute a degenerating society, where the Americanized "high quality of life" could no longer be retained.

Second, it is the container-like space under the gaze of Man, where separate things stay, move, and collide, that fosters a hostile Self-Other relationship. This spatiality takes for granted the cut of the wor(l)d, since only when "*thing-ness*" makes sense does the space different from, but allowing for the display of "*things*," makes sense. It means everything is exteriorized from everything else, thus one's existing, or being *there* ('Dasein'), necessitates the expulsion of another from *there*, or even worse, the suppression or eradication of another. Both statements knit together such a philosophy of space and their argument of crisis by placing the United States in "either…or" competition with Others. For example, *A Nation at Risk* (NCEE, 1983) used a war metaphor to describe the "unimaginable" fact that "others are matching and surpassing our educational attainments": "If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might have viewed it as an act of war" (p. 13). And as a consequence of the "educational disarmament," America would lose its competitive edge in world markets—another war lost to its "determined, well-educated, and strongly motivated competitors" (p. 14). *Rising Above the Gathering Storm* (NAS, NAE & IOM, 2005) paralleled the crisis that America is faced up against with the economic advantage that Others are winning, "the scientific and technical building blocks of our economic leadership are eroding at a time when many other nations are gathering strength" (p. 2). It worried about the disturbance of the established economical order in which the States enjoys an overwhelming superiority. The development of Others is good insofar as America's leading position in economy/science/technology is secured, "We strongly believe that a worldwide strengthening will benefit the world's economy—particularly in the creation of jobs in countries that are far less well-off than the United States…We fear about the abruptness with which a lead in science and technology can be lost—and the difficulty of recovering a lead once lost" (p. 2).

Third, it is the one-directional, linear temporality, from which 'modernist' assumptions of progress arise, that sets a "global future" the rational subjects in a free, democratic society are destined to reach. Ignoring the messiness of histories and the limitless possibilities of pasts and futures being synthesized in every present, this temporality prescribes the routine of progress, starting from *the* past, as constructed by *the* institutionalized History, via *the* present, where human ascends to Man through education, to *the* future, which witnesses the everlasting glory of liberal democracy. Any deviation from the routine will lead to a disastrous end: A wasted present will lead to a dystopian future. *A Nation at Risk* (NCEE, 1983) attributed America's leadership in world economy at present to "an abundance of natural resources…inexhaustible human enthusiasm, and…our relative isolation from the malignant problems of older civilizations" in the past. It warned that the unremarkable status quo of education in U.S. has "squandered the gains in student achievement made in the wake of the Sputnik challenge" (p. 13) and only through hard work for excellence in education now could the nation save itself from a pessimistic future. *Rising above the gathering storm* (NAS, NAE & IOM, 2005) saw the success of the U.S. economy today as the return of past investments in STEM education and research, "That vitality is derived in large part from the productivity of well-trained people and the steady stream of scientific and technical innovations they produce" (p.1). Sequentially, devoting time, energy, money, and human resources to the undertaking of STEM education and research at present will promise future generations worthwhile results "that our children and grandchildren will inherit ever-greater opportunities" (p. 1).

The exaltation of the "rational" subject, the array of discrete things in a container-like space for the scrutiny of the "rational" subject, and the onward movement of the rational" subject along a linear timeline—clearly, the historical corpus of Man, such as Descartes' *cogito* and Kant's transcendental consciousness, gets itself revitalized in the two statements for the specific purpose of advocating STEM education. Here a regularity could be defined "between objects, types of statement, concepts, or thematic choices" (Foucault, 1969/2013, p. 38): STEM education will save the individual and the nation from an imminent *crisis*, a dystopia where Man falls. Using Foucault's term, the 'discursive formation' of STEM education reveals such a "regularity."

So far, this section has discussed the philosophical foundation and discursive formation of STEM education, delineating how it is grounded in the historical narratives of Man and the Man-anchored space and time. More concisely and exactly, it is the humanist subject, Man, with his panoptic view, and the all-encompassing space necessitated by Man, that underlie STEM education, since everything, including Man's yet-to-be-perfect self, the living *I* in Descartes' *cogito*, has to be displayed in the space for Man to cast down his eyes on. The change, process, or temporal existence of the living *I* has to be objectified, meaning time has to become an additional dimension of spatiality that the *I* at present differs from, and external to the *I* in the past and the *I* in the future: The non-repeatability of history called "progress."

To be clear, the discursive formation of STEM education was not accomplished solely through the two statements *A nation at risk* and *Rising above the gathering storm*, and at the particular point in time when the statements were publicized. The national dialogue over STEM education has been carrying on through various statements, which, though answering to different contexts, revolve around the debates on *crisis*. To list but a few: A NSF-funded report *Into the eye of the storm: Assessing the evidence on science and engineering education, quality and workforce demand* (Lowell & Salzman, 2007) rejected the analysis and conclusion of *A nation at risk* by proving that U.S. schools are doing well in providing quality science/math education and preparing students for science and engineering jobs; The committee that produced *Rising above the gathering storm* in 2005 revisited America's academic/economic competitiveness in 2011 and concluded in *Rising above the gathering storm, Revisited* that "our nation's outlook has not improved but rather has worsened" (NAS, NAE & IOM, 2011, p. 3); And one of the latest STEM "talks," *Vision 2030* (National Science Board [NSB], 2020), released by the policy making board of the NSF, reaffirmed the urgency of retaining America's lead in fundamental research and increasing its citizens' STEM skills due to the fierce challenge posed to the U.S. by other nations. *Crisis* becomes the commonsense idea permeating the discourse of STEM education: The impending crisis is either a fallacy because America has succeeded in STEM education or a fact because America has suffered from a flawed education system and found difficult to make any improvements.

But “we have enough commonsense ideas, backed by decades of research, to significantly improve American schools. The missing ingredient isn’t even educational at all. It’s political” (Strong American Schools [SAS], 2007, p. 4). Now that “we have enough commonsense ideas” that STEM education is the rescue of American education and economy, what is missing is “political,” i.e., the politics behind the actual enactment of STEM education. The next section will proceed to analyze the power dynamics inherent in STEM education practices through Sylvia Wynter’s (2003) “descriptive statement” of Man.

2.4 THE MASTER CODE OF MAN: THE POLITICS BEHIND STEM EDUCATION’S UNFUFILLED PROMISES

Enormous efforts have been made to support STEM education financially, legislatively, and professionally. For example, in a report prepared for members and committees of Congress, the federal investments in STEM education are reviewed,

> Over 300 bills containing just the term “science education” were introduced in the 20 years between the 105th (1997-1998) and 115th (2017-2018) Congresses. Agency reauthorization bills often contain STEM education-related provisions, and at least 14 federal agencies conduct STEM education programs or activities. The annual federal investment in STEM education programs, while difficult to estimate, is typically considered to be around $3 billion (Granovskiy, 2018, pp. 1-2).

And fiscal year 2020 saw a mix of budget increases for federal STEM education programs, with the largest shares (in terms of the number of programs and the amount of investment) housed at the Department of Education, the National Science Foundation, and the National Aeronautics and Space Administration, whose priority funding areas include the STEM school and teacher development, the education and innovation research, the minority service, as well as the preparation of STEM graduates for the workforce of the future (American Institute of Physics [AIP], 2020).

Besides providing funding, the federal government also puts forward laws to tackle persistent and rising problems in STEM education. For instance, Women and Minorities in STEM Booster Act of 2013 (S. 288) and STEM Opportunities Act of 2013 (H. R. 1358) meant to minimize biases based on gender, ethnicity, and race in STEM education and employment. STEM Jobs Act of 2013 (S. 303) and STEM Visa Act of 2013 (H. R. 459) sought to maximize the STEM talent pool by availing foreign students, who hold a STEM-major doctorate degree from an American institute, of more visas. The American Innovation and Competitiveness Act of 2017 (P. L. 114-329) and Inspiring the Next Space Pioneers, Innovators, Researchers, and Explorers (INSPIRE) Women Act of 2017 (P. L. 115-7) aimed to increase the participation of underrepresented groups in STEM fields and to encourage women to pursue careers in aerospace. And the latest move, the reintroduction of the Rural STEM Education Act on April 27, 2021, attempted to improve STEM education and training access in rural communities.

Endeavors are also made on the part of STEM professionals and enthusiasts. “A simple Google search with the term ‘STEM’, ‘STEM education’, or ‘STEM education research’ all returned more than 450,000,000 items,” Li et al. (2020) comment, “Such voluminous information shows the rapidly evolving and vibrant field of STEM education and sheds light on the volume of STEM education research” (n. p.). The “voluminous information” is consistently an integration of academic thought and practical experience directed towards the cultivation of the qualified STEM professional and a STEM literate general citizenry. A look at the Illinois Science, Technology, Engineering, and Mathematics Education Initiative (I-STEM), a university-based, multidisciplinary, and cross-organizational collaboration, will help reveal how "vibrant" the STEM research-practice is. I-STEM is a coalition of departments, colleges, and research institutes at the University of Illinois, which work in synchrony with local and external partners including school districts, government agencies, and STEM professional organizations, to promote STEM outreach, foster undergraduate and graduate STEM education reform, improve STEM teacher preparation and development, as well as shape STEM policies at local, state, and national levels (I-STEM, 2021). Thanks to its loose and flexible delineation of "STEM," I-STEM involves units such as College of Fine and Applied Arts, School of Social work, and College of Law, and is capable of offering unique service to teachers and students. For example, in 2020 I-STEM developed a "Musical Magnetism" curriculum, which uses hip hop or rap, a medium popular among teenagers, as the "hook," to familiarize students with materials science, magnetism, and scientific communication. At the end of the course, students "teamed up to create then present raps about specific areas of magnetism" (I-STEM, 2021, p. 19).

Despite all the good intentions, strong determination, prompt action, and hard work, research shows concerns regarding the current condition of U.S. STEM education. First and foremost, there is a persistent plea for increasing the opportunity for members of underrepresented groups to enter STEM majors and careers, as evidenced by the high frequency of legislative efforts attending to the differences/gaps between different demographic groups when contextualized in STEM fields. Retrieving official records of American students' academic achievements in mathematics and science at the elementary and secondary levels, their postsecondary degree attainment, and their occupational outcomes, gaps and differences between different demographic groups are clear.

Checking the 4th and 8th grade National Assessment of Educational Progress [NAEP] mathematics assessments in 2019, an 18-plus point gap existed between the average mathematics scores of white students and their black and Hispanic counterparts at each grade, and in the case of science, the point gap is 24-plus (NAEP, 2020). The finding is not surprising though, as black and Hispanic students have been lagging far behind their white and Asian peers throughout the history of the NAEP assessments. Another index of STEM education's effectiveness for different groups is their postsecondary degree attainment in science and engineering. The following table is drawn from the NSF survey on recipients of science and engineering bachelor's degrees from 2008 to 2018 (NSF, 2021); It shows the percentage of students of different race/ethnicity earning science and engineering degrees in 2008 and 2018:

DEGREE	RACE/ETHNICITY	2008	2018
Computer and information sciences	Hispanic or Latino	7.9%	11.4%
	Black or African American	10.8%	8.9%
	White	62.4%	54.7%
	Asian or Pacific Islanders	8.4%	16.4%
Mathematics	Hispanic or Latino	6.1%	11.4%
	Black or African American	5.3%	4.9%
	White	72.1%	62.1%
	Asian or Pacific Islanders	10%	14.4%
Physical Sciences	Hispanic or Latino	0.63%	0.39%
	Black or African American	6.4%	6.2%
	White	68.4%	62.3%
	Asian or Pacific Islanders	11.7%	11.8%
Engineering	Hispanic or Latino	8%	12.2%
	Black or African American	4.7%	4.3%

	White	69%	64.3%
	Asian or Pacific Islanders	12.8%	12.4%

Table 1. Percentage of recipients of bachelor's degrees in science and engineering, by ethnicity

Table 1 indicates that in 2018, despite some increases of degree attainment for Hispanic/Latino, they continued to make up a lower share of STEM graduates relative to their share of the population, which is 18.5% according to the U.S. Census Bureau [USCB] census data (USCB, 2020), and the black/African Americans were not only highly underrepresented in STEM degree attainment considering their constitution of the U.S. population (13.4%) (USCB, 2020), but also decreased in degree completion in all STEM subfields. Finally, relatively small percentages of undergraduate degrees in engineering and computer science were awarded to women both in 2008 and 2018, as shown by the following table:

DEGREE	2008	2018
Computer and information sciences	17.4%	19.2%
Mathematics	44%	41.5%
Physical Sciences	41.3%	40.7%
Engineering	18.5%	22.5%

Table 2. Percentage of female recipients of bachelor's degrees in science and engineering

The need for increasing gender, racial and ethnic diversity is also seen in the STEM workforce. The NSF investigates the STEM employment status, finding that black Americans account for 7.45% of employed science and engineering professionals in 2019, and Hispanic/Latino, 9.08% (NSF, 2019). The Pew Research Center, "a nonpartisan fact tank" that informs the public about key issues nationwide or worldwide (2021, p. 2), draws on multiple sources of federal government data and sketches out current trends in STEM occupations. Mobilizing a broad-based definition of "STEM" jobs, which includes "any of 74 standard occupations in life sciences, physical and Earth sciences, engineering and architecture, computer and math occupations as well as health-related occupations including healthcare providers and technicians" (p. 5), it produces findings varying from the NSF survey numerically but revealing similar problems, i.e., "black and Hispanic workers remain underrepresented in the STEM workforce" (p. 4), "women make up a quarter or fewer of workers in computing and engineering, are overrepresented in health-related jobs" (p. 7), and "STEM workers often earn more than others, but there are sizable pay gaps for the typical STEM worker by race, gender and ethnicity" (p. 11): In 2019, amongst full-time, year-round STEM workers ages 25 and older, women earned less than men, so did black and Hispanic/Latino than their white and Asian counterparts.

Second, heated debates over the efficacy of STEM education for securing employment and curing social ills related to economic lethargy remain ongoing. The most frequently asked questions include: Is the STEM worker shortage a myth or a fact? To what extent should education in general be responsible for 'a nation at risk', and to what extent is STEM education specifically a guarantee of jobs and of the basic skills, necessary for living a civilized life? Defining STEM occupations as "computer and mathematical, architecture and engineering, and life and physical science occupations, as well as managerial and postsecondary teaching occupations related to these functional areas and sales occupations requiring scientific or technical knowledge at the postsecondary level," the U. S. Bureau of Labor Statistics (USBLA) predicts that the overall employment rates in the U.S. will increase by 3.7% from 2019 to 2029, and STEM jobs will increase by 8% in the same period of time (2021). Though the demand for STEM workers looks high, the USCB's 2019 American Community Survey 1-year estimates shows an excess of supply over demand: 14% of all employed college graduates ages 25-64 (50 million) were employed in a STEM occupation (computer, mathematicians, engineers, life scientists, physical scientists, and social scientists) in 2019, while 36.6% of them reported an undergraduate degree in science and engineering, meaning only 38% of STEM degree recipients were actually working as a STEM professional. An article published by USBLA analyzes the STEM labor supply and demand, suggesting that there simultaneously is and is not a STEM worker shortage, as STEM job opportunities differ by fields and degrees. The manufacturing industry needs more machinists and technicians below the bachelor's degree level, areas like software development, mobile application development, data science, and petroleum engineering have consistent demand for employees with a bachelor's or master's degree, academics have an oversupply of Ph.D. graduates while other fields in the government sector (nuclear engineering, materials science, and thermohydraulic engineering) and in industry (petroleum engineering, process engineering, and computer engineering) have unfilled positions for graduates with STEM doctorates (Xue & Larson, 2015). Situating education in a wider social context and retrieving data of STEM education (enrollment, test scores and degree attainment) and employment longitudinally, another report finds no evidence to justify concerns about the decline of the U.S. (STME) education system and its socioeconomical consequences in terms that, first, education alone neither leads to nor solves "bigger" socioeconomical problems such as "stagnant wages, increasing inequality, high unemployment, moral deterioration, and overall economic lethargy" (Salzman, 2018, p. 9). Secondly, the current STEM "pipeline" has improved students' academic achievements according domestic/international test scores and produced ample graduates in response to STEM labor market demand: "Colleges historically produce between 40 to 100% more STEM graduates, depending on the field, than are hired into STEM occupations each year" (p. 23). And third, STEM skills, as qualities of “an informed citizenry” (p. 16), are too broad and too basic to be cultivated under “an aggregate ‘STEM major’ category” (p. 17).

The U.S. national agenda for education has always pinned the polity’s hope on equipping its citizens with scientific knowledge, dating back to the First Congress when President George Washington called upon Congress to promote science and literature for the sake of “public happiness” (George Washington, 1790, n. p.), to the Space Race ignited by the launch of the Soviet Union Satellite “Sputnik” early in the Cold War, to the landmark event contributing to the ever-growing assertion of “crisis,” the publication of *A nation at risk* in 1983, to the endorsement from scientifical professionals, as marked by the release of the *Rising above the gathering storm* in 2005, on the claim that the United States would be outperformed by other nations economically if no due action was taken upon STEM education, and to the ongoing deep policy shifts driven by the rise of anti-China anger at present, America’s new “Sputnik moment” with China (Manning, 2020, n. p.). It is promised that through STEM education the U.S. citizen will be informed enough to perform his political and economic function, the historically marginalized groups will benefit in particular, and the nation will maintain its economical vividness. However, such promises remain unfulfilled considering the oversupply of STEM workers, the persistence of gaps in academic performance/occupational outcomes, and the complexity of economical competitions.

The rapid expansion of STEM programs itself does not suffice to break through the impasse STEM education now reaches, which is but an incarnation of various historical entanglements. For instance, a report produced by the National Academies of Sciences, Engineering, and Medicine [NASEM] attributes the underrepresentation of black students and workers in science, engineering, and medicine to structural racism: “We have to recognize that bias and racism are the fundamental causes for the lack of Black men and women pursuing careers in science, engineering, and medicine" (NASEM, 2020, p. 4). When race is naturalized as biological or cultural, it becomes legitimate to ascribe certain traits to a 'racial' group, like historically black Americans were believed to be of "low intelligence, poor judgement, poor parenting, and the inability to control 'bestial sexual urges'" that their sole engagement in science, the "privileged discipline" "treated as gospel truth" (p. 16), was to be used as the object of scientific, especially medical, research: "There is not a single mulatto who has done credible scientific work" (Cattell, 1913, as quoted in NASEM, p. 16). As "a system of power" (p. 10), racism is ingrained into the very fabric of American life, operating through mechanisms like "racial residential segregation," "unequitable public-school funding," use of standardized tests as "important predicators" of students' success while devaluing other epistemological assets (p. 55), etc., and in times of the COVID-19 crisis, racism is exacerbating "fear and 'otherization'" (p. 45). Therefore, people aiming at increasing the presence of black Americans in STEM education and profession will have to participate in a general anti-racism enterprise in the social context beyond (STEM) education itself. Another report names the key to addressing women's underrepresentation in science, engineering, and medicine as addressing sexism and racism, "Bias, discrimination, and harassment are major drivers of the underrepresentation of women in STEMM [STEM plus Medicine] … and are often experienced more overtly and intensely by women of intersecting identities (e.g., women of color, women with disabilities, LGBTQIA+ women)" (NASEM, 2020, p. 2). Regarding the surplus of STEM workers over demand, research blames corporate, especially Tech Barons, and government for unproportionally expanding the STEM talent pool so as to lower the labor costs as much as possible. Charette (2016) manifests how Microsoft manipulated the USBL data of 2012-2022 STEM-related job openings to level up the public anxiety about the inadequate supply of workers with computer-science postsecondary degrees, and how the Obama administration "trumpeted the need for 1 million more students with bachelor's or associate's degrees in STEM subjects" with "little publicly available quantitative analysis backing this call" (p. 85). For him, the "perpetual crisis" (p. 82) looming up in front of America, which grounds the STEM education discourse, is "a riddle, wrapped in a mystery, inside an enigma" and only from the perspective of "interest"—national interest and corporate interest—this "riddle" is to be untangled (p. 85). Cashman (2015) surveys the USBL data of 2006-2014 year-over-year nominal wage growth for STEM subdomain occupations (occupations in Health, Social Science, Architecture, and Life/Physical Science/Engineering/Mathematics/Information Technology), finding that "all of these subdomains fell after the Great Recession, and none have recovered. All are under 2.0 percent, with wage growth in the Social Science Subdomain close to zero" (n. p.). An examination of 2009-2014 year-over-year nominal wage growth for major and select STEM occupations (computer programmers, database administrators, system software developers, etc.) reveals a similar trend where wage growth for all groups was under 3.0 percent. The author concludes that the so-called STEM shortage is the employer's strategy to produce more-than-enough qualified workers to increase the bargaining power in salary negotiation. Salzman (2015) reports to the Senate Committee on the Judiciary that the U.S. is capable of educating its own "top performing" STEM graduates, whose number "far exceeds the hiring need of the STEM industries" (p. 2), and that the large use of guest workers will distort not only the current STEM labor market but also the U.S. higher education system by "providing incentives for colleges or universities" (p. 3) to establish, or expand current STEM programs and attract more foreign students who might influence the future market.

Here are some ideas of the historical entanglements which account for the dilemma that STEM education is trapped in: Racism, sexism, commercialism, and nationalism. If we kept on going, more "-isms" would add up: Ageism, ableism, classism, homophobism, genderism, so on and so forth. Such "-isms" are but concretizations of a particular West Europe's cosmogony—what it is meant to be human and to dream up the world—singularizing itself and overrepresenting all cosmogonies: A cishet (relating to genderism, homophobism), white (to racism) male (to sexism) of European descent, who is mentally rational (manifested by secularized science) and physically healthy (to ableism), is endowed (by God) with the sacred right of maintaining the order of liberal (to commercialism) democracy (to nationalism). Without de-neutralizing the universality of such a humanist subject, Man, sufferings of those other-than-Man would not be possibly alleviated.

Sylvia Wynter offers an insightful explanation of the structural problems in "Western" societies as in relation to the humanist subject, Man. She historicizes the "descriptive statements" of humanness, which set Man as the "Western European population" *referent-we* [emphasis original]' (Wynter and McKittrick, 2015, p. 24). Before Europe's "discovery" of the New World in 1492, the binary code of human is clergy/laymen. From the late 15th to 18th century, human is secularized and naturalized (as the subject and object of natural sciences, including biology, and as different from "supernatural" or "theological") so that the transition from religious society to modern nation-state and the launch of modern sciences could be made possible. Wynter refers to human epitomized as such as *Man1*: "…the new order of adaptive truth [of the West's own self-conception]…had begun to be put in place with the rise to hegemony of the modern state, based on the new descriptive statement of the human, Man, as primarily a political subject" and "a lawlike part of the systemic representational shift…[was] made out of the order of discourse that had been elaborated on the basis of the Judeo-Christian Spirit/Flesh organizing principle…to the new rational/irrational organizing principle and master code" (Wynter, 2003, p. 300). From the 19th century to present, human is further framed within the paradigm of Evolution, especially that of Darwin's natural selection, which was brought in 'the wider context of the intellectual revolution of Liberal or economic (rather than civic) political humanism … from the end of the eighteenth century onwards by the intellectuals of the bourgeoisie' (p. 322), like Adam Smith; Namely, human is written as of "differential degrees of evolutionary selectedness/eugenicity and/or dysselectedness/dysgenicity" (p. 316) biologically, and as of deferential degrees of rational self-interest and competitiveness economically. Wynter refers to human as such as *Man*2, claiming that it is Man1, Man2, and the narrative of the secularized Christianity weaving together that function as the "descriptive statements" of Man which overrepresent other notions of the human "genres" of humanness: "…as Christian becomes *Man1* (as political subject), then as *Man1* becomes *Man2* (as a bio-economic subject), from the end of the eighteenth century onwards, each of these new descriptive statements will nevertheless remain inscribed within the framework of a specific secularizing reformulation of that matrix Judeo-Christian Grand Narrative" (p. 318).

The predominance of the "descriptive statements" of Man has consequences. "All the colonialized darker-skinned natives of the world and the darker-skinned poorer European people themselves" (Fitzpatrick, 1992, as cited in Ferreira da Silva, 2015, pp. 94–95), depending on how successfully they have "evolved" towards Man, get located at "appropriate" levels in the political, biological, and economic hierarchy where Man is the Norm. Imperial expansion and colonial violence are justified because these non/less-than-humans are, at the best, in need of salvation, and at the worst, in need of suppression or eradication as they are Others menacing Man's supremacy and order.

When the cacophonies of "humanness" are reduced to the monologue of Man, ethical concerns arise. Looking back at the news report and the TV series at the beginning of this chapter, no wonder elderly people, who were no longer fully "human" bio-economically, were left to die in the nursing homes of Spain during the Pandemic, and no wonder irresolvable conflicts and poignant anxieties arose as Man's distinctiveness, his rationality and consciousness, was lost at the dawn of artificial intelligence and consciousness.

2.5 CYBERNETICS AS THE UNCONCIOUS OF MODERN EDUCATION

The previous sections have discussed the philosophical foundation and the cultural discourse that make possible a neologism called "STEM education," as well as the unfulfilled promises of STEM education to improve "human" conditions bio-economically and politically due to its reduction of human to Man. This section will illustrate how cybernetic thinking grounds modern education's procedural, managerial treatment of "human" and its theories of knowledge. As cybernetics is the herald and bedrock of the socio-technological movement called digitalization, this section sets the stage for next chapter's illustration that digitalization is a more recent condition of possibility for STEM education.

Previous research has critically reflected on the influence of the science of cybernetics and information theory in the field of curriculum. For example, Ivens (2018) examines how cybernetics as a technology to manage the reform of American social structures is ingrained into the organizing schema of the Tyler Rationale and functions through algorithmic strategies, systems-based educational research, programming, and educational policies to make up new kinds of people aligned with the modernization project of subject-making. Lee (2021) investigates how cybernetics rationales are embodied in the historical shift of teachers' positionality from a "participant" to a "participant observer" in action research during the post-World War Two period. She demonstrates that, although action research has empowered teachers to have an autonomous sense of agency as "teacher-researchers," the feedback structure and circular causality inherent in the mechanically applicable rules of action research leave little room for teachers as autonomous agents to consider the empirical representations in relation to cultural, historical, and social conditions.

This section, however, intends to theorize cybernetics in relation to the onto-epistemological shift marked as "modernity" and demonstrate cybernetics as the unconscious of modern education. It proceeds by, first, briefly introducing cybernetics in terms of its etymology, key concepts, and groundbreaking proposition, and second, showing cybernetics as the continuation and culmination of the onto-epistemological movement which sets the foundation of so-called modernity and modern disciplines in the humanities, including education. This section concludes that modern education is not "all of a sudden" thrown into the weave of digitalization but has long been "hard-wired" as ready for digits. Following this line, the next chapter will detail the content, pedagogy, and motivation/goal of STEM education in the U.S. and explicate that STEM education emerges from a "home" where human, despite the contingency indispensable to his "organic" development, should and could be designed, measured, and controlled through cybernetics rationales.

2.5.1 Cybernetics: Etymology, Key Concepts, and the Collapse of the Distinction between *Epistêmê* and *Tekhnê*

> It is the purpose of Cybernetics to develop a language and techniques that will enable us indeed to attack the problem of control and communication in general, but also to find the proper repertory of ideas and techniques to classify their particular manifestations under certain concepts.
>
> NORBERT WIENER, *The Human Use of Human Beings*

In 1950, Wiener revisited the revolutionary concept "cybernetics" he invented and introduced to the Anglo world[1] in 1948, whose debut marks the establishment of "the entire field of control and communication theory, whether in the machine or in the animal" (Wiener, 1948/2019, p. 18).

"Cybernetics" is derived from the Greek word *kubernētēs* or *χυβερνήτης* (meaning "steersman") (Wiener, 1948/2019, p. 18; Wiener, 1950/1989, p. 15), which appears in Plato and Aristotle's texts as a *tekhnê* (currently translated as "art" or "craft") and is always discussed alongside the *tekhnê* of medicine. For example, in Plato's *Alcibiades,* "*aretes kybernetikes*" refers to "intelligence or skill in navigation" (Plato, 1892, p. 508), and in Aristotle's *Nicomachean Ethics*, "*Kybernetike tekhnê*" means "the art of navigation" (Aristotle, 1999, p. 22, p. 38).

Plato regards *tekhnê* as associated with knowing how to do certain teleological or goal-oriented activities. For him, "every art has an interest" (Plato, 1888, p. 19) and provides an account of saying and doing based on the understanding of that interest, like medicine considers "the interest of the body" (p. 19). *Kybernetikes* is to "provide and prescribe for the interest of the sailor" (p. 20) and in accordance with such goals it offers schemes. *Tekhnê* produces kinds of knowledge able "to explain or to give a reason of the nature of its own applications" (Plato, 1892, p. 346) and should not be confused with *epistêmê* from which the umbrella term for theories of knowledge, "epistemology," stems. *Epistêmê* for Plato "is relative to being and knows being" (Plato, 1888, p. 175), meaning it pertains to the real and indicates knowledge of the forms, like the forms for the beautiful, the good, and the just. Plato seems to use *epistêmê* to designate the theoretical component of *tekhnê*, like the physician knows health by medical knowledge (*epistêmê*) (Plato, 1892, p. 30). However, *epistêmê* differs from *tekhnê* mainly in terms that *epistêmê* has as its objects forms, which are exempt from any changes, "absolute, separate, simple, and everlasting" (p. 581), and thus has no product separate from the didactic thinking that helps recall the forms, while *tekhnê* regulates behaviors amidst transitory phenomena to imitate forms, realizing a goal separate from its activities, like medicine considers health rather than the interest of the medicine and *kybernetikes* considers navigation safety at sea rather than mere sailing (Plato, 1888, pp. 20-24).

Unlike Plato who holds *tekhnê* as far from being "real" and thus deserving not as much attention as *epistêmê does,* Aristotle addresses the importance of *tekhnê* in governing productive (*poiêtikê*) action and maps out the strong distinction between *epistêmê and tekhnê.* In the *Nicomachean Ethics* (Aristotle, 1999), Aristotle tells the part of the soul which grasps the rational principle from that which deals with the irrational, and further divides the part grasping the rational principle into two parts: "one by which we contemplate the kind of things whose originative causes are invariable, and one by which we contemplate variable things" (p. 91-92). He calls the former "the scientific[2]" (*ἐπιστημονικὸν* or *epistemonikón*) and the latter, "the calculative," as "to deliberate and to calculate are the same thing" and "no one deliberates about the invariable" (p. 92). Belonging to the calculative part of the soul is practical thought (*dianoia praktikê*), and the kind of practical thought for the sake of an end—making or producing something—is *tekhnê* or art: "Art is identical with a state of capacity to make, involving a true course of reasoning" and "all art is concerned with coming into being" (p. 94). Such practical thought shall not be confused with *epistêmê*, the theoretical thought (*theôrêtikê dianoia*) pertaining to the scientific part of the soul, which accounts for the particular state of forms, i.e., the very nature of everything, in the soul. In *Metaphysics* (Aristotle, 1801), Aristotle illustrates the distinction between *epistêmê and tekhnê* through the example of medicine. Medicine as an art refers to "a state of capacity…involving a true course of reasoning" to produce health and health is "reason in the soul and in science" (p. 166) that serves as the very cause, starting point, and end of medicine. Based on the knowledge of health and disease (the absence of health), reasoned are the conditions that can be brought into existence by the physician to realize the state of health in the soul (p. 166). Aristotle explains,

> In this manner, [the physician] perpetually reasons, until he arrives at that which he is able to effect. Afterwards, that motion which now begins from this, is called the

> making which leads to health. So that it happens after a manner, that health is produced from health…viz. that which possesses matter is produced from that which is without matter (p.166).

Thus, for Aristotle, there is no *epistêmê* of accident (Aristotle, 1801, p. 147) while *tekhnê* always relates to accident: "in a sense chance and art are concerned with the same objects; as Agathon says, 'art loves chance and chance loves art'" (Aristotle, 1999, p. 94).

The distinction between *epistêmê and tekhnê* no longer holds in Wiener's explication of cybernetics, where cybernetics consists of not only "scientific" concepts and methods that apply to "the problem of control and communication in general" (Wiener, 1950/1989, p. 17), but also of "ideas and techniques" that translate such a domain of true knowledge into "particular manifestations" (p. 17) for the purpose of control and communication within concrete situations. To understand the groundbreaking transition from *aretes kybernetikes*, a mere *tekhnê*, to cybernetics, a language stating what is intellectually certain and a set of techniques dealing with particularities and contingencies, it is necessary to embed cybernetics in intellectual movements that are historically interwoven with it. The following text will visit historical trends that Wiener regards as contributing to the rise of cybernetics[3], explain ideas central to cybernetics—control and communication—in relation to these trends, and sketch the paradigm shift of knowledge and knowing that cybernetics is grounded in.

Above all, for Wiener, Gottfried Wilhelm Leibniz (1646-1716) is "a patron saint for cybernetics out of the history of science" (Wiener, 1948/2019, p. 19) as Leibniz's vision of a universal symbolism and a calculus of reasoning establishes a norm of how we should think if we want to solve real-world problems and meanwhile get true knowledge. Leibniz asserts that thinking is not possible without the mediation of signs, while our natural language does not suffice for "universal" human reasonings, because it is bounded to the oral discourse and makes thinking operate with concrete things, which are of fleeting nature. To find a “language” of permanent “material” stability, Leibniz resorts to mathematics, based on which people had already developed non-linguistic arts of writing in the 15th and 16th centuries, like the written reckoning and symbolic algebra. He builds a system of “characters,” or in his term, *calculi*, that could encode any logical statement with mathematical precision and allows the apparently finite human mind to grasp the infinitely many attributes of things. Here is an example where Leibniz assigns natural numbers to the subject and predicate of a proposition so that the truth can be “read off” mathematically: “For example, since ‘man’ is ‘rational animal’, if the number of ‘animal’, *a*, is 2, and the number of ‘rational’, *r*, is 3, then the number of ‘man’, *m*, will be the same as *a***r*, in this example 2*3 or 6” (Leibniz, 1679/1966, p. 17). The concept “man” is attained through the algebra of concepts “animal” and “rational,” and, universally, any complex concept proceeds from a number of simple concepts in a manner similar to arithmetic multiplication. In this way, the externalization and mechanization of human reason becomes possible, and “essences” of things turn into “fundamentally nothing but the possibility of the thing under consideration” (Leibniz, 1765/1981, p. 293), which are “everlasting because they only concern possibilities” (p. 296). “Theories of knowledge” converge with “techniques” at this point.

Leibniz sets the stage for the emergence of cybernetics and the machine called the computer in so far as he treats possibilities as essential to living and knowing and relies on mathematics to idealize and externalize the process of thought (in fact, he invented a computing and reasoning machine known as the stepped reckoner or Leibniz calculator). In line with him, there arose multiple intellectual movements among which Wiener highlights biology’s embrace of the theory of evolution and physics’ integration of possibilities. The strict Newtonian system is a closed mechanics with preset postulates, in which the past and future positions of the moving bodies are easily and precisely computed based on the knowledge of their present positions, velocities, and masses. With little consideration of frictional processes, Newtonian time is reversible, as exemplified by the motion of the planets in the solar system, which is of predictable cycles and extends backward and forward in time: "The music of the spheres is a palindrome, and the book of astronomy reads the same backward as forward" (Wiener, 1948/2019, p. 45). However, biology proves the Newtonian pattern not fitting in with its frame, as Wiener explains,

> The biological sciences certainly have their full share of one-way phenomena. Birth is not the exact reverse of death, nor is anabolism—the building up of tissues—the exact reverse of catabolism—their breaking down. The division of cells does not follow a pattern symmetrical in time, nor does the union of the germ cells to form the fertilized ovum. The individual is an arrow pointed through time in one way, and the race is equally directed from the past into the future (p. 51).

This one-directional, irreversible time compatible with the theory of evolution opens up the question of existence, as accidents, chances, or possibilities are no longer what are to be avoided but are necessary for living and knowing, and they account for the transition from the preformed to the self-organized.

Another tradition that Wiener draws on is statistical mechanics co-founded by James Clerk Maxwell (1831-1879), Ludwig Eduard Boltzmann (1844-1906), and Josiah Willard Gibbs (1839-1903). Statistical mechanics, as demonstrated by its name, is the integration of statistics into Newtonian mechanics: It explains thermodynamic laws in terms of the statistical properties of ensembles of all possible states of a physical system composed of many particles, as Wiener explicates,

> The succession of names Maxwell-Boltzmann-Gibbs represents a progressive reduction of thermodynamics to statistical mechanics: that is, a reduction of the phenomena concerning heat and temperature to phenomena in which a Newtonian mechanics is applied to a situation in which we deal not with a single dynamical system but with a statistical distribution of dynamical systems; and in which our conclusions concern not all such systems but an overwhelming majority of them (p. 53).

Statistical mechanics informs Wiener in several ways. First, chance becomes integral to the "scientific" domain of physics, as Hill notes, "[Gibbs'] applications of probability demonstrated, Wiener said, that chance is part of the 'warp and weft' of physics" (Hill, 2019, p. xviii). Second, chance becomes calculable with the correct approach and due instrument. Maxwell, Boltzmann, and Gibbs have all explained the irreversibility of macroscopic physical processes in probabilistic terms and transformed physical chemistry into a rigorous *inductive* science. Inductive approach aims at detecting patterns, formulating hypotheses, and then developing theories based on specific observations, meaning that knowledge arises from time series obtained by experience, or, from history. Moreover, they resort to mathematics to represent and compute chance[4], as exemplified by the famous concept "entropy," which is "primarily a property of regions in phase space and expresses the logarithm of their probability measure" (Wiener, 1948/2019, p. 80).

It is important to understand the key concepts of cybernetics in relation to the above-mentioned intellectual movements. As told by the title of Wiener's famous book of 1948, two concepts central to cybernetics are "control" and "communication." The idea of control refers to a system's capacity to perform a function according to a pre-determined set of instructions even under unexpected or uncertain circumstances. Control is realized when the system triggers a change in its environment and this change in turn triggers another change in the system (so-called "circular causality" or "feedback"), or in Wiener's words, "when we desire a motion to follow a given pattern, the difference between this pattern and the actually performed motion is used as a new input to cause the part regulated to move in such a way as to bring its motion closer to that given by the pattern" (Wiener, 1948/2019, p. 11). The construction of "control" demonstrates the necessity of chance or contingency for a system to "understand" the world and maintain its functionality, as informed by the theory of evolution. Also, chance or contingency is approached in terms of "the pattern," i.e., distribution probability, rather than with reference to concrete "things" that realize the pattern, as closely related to Leibniz's universal symbolism and the Maxwell-Boltzmann-Gibbs statistics. For the purpose of engineering, binary digits (a 0 or a 1), which interpret chance or contingency as "a choice between two equally probable simple alternatives, one or the other of which is bound to happen" (Wiener, 1948/2019, p. 86) and allow the apparatus to operate in a more economical way than decimals would do, are widely accepted by scholars who have laid the foundations for the modern discipline of communication: "[The adoption of binary digits] occurred at about the same time to several writers, among them the statistician R. A. Fisher, Dr. Shannon of the Bell Telephone Laboratories, and the author [Wiener]" (Wiener, 1948/2019, p. 17).

For Wiener, "the problems of control engineering and of communication engineering were inseparable" (Wiener, 1948/2019, p. 14), and he exemplifies how the apparatus of control, the animal and the machine alike, turn into automata that are goal-oriented and self-acting. For instance, when what is observed in phenomena by a system is conveyed as a time series, "a numerical quantity, or a sequence of numerical quantities, distributed in time" (Wiener, 1948/2019, p. 85), the prediction of the future of the time series is done by "by some sort of operator on its past" (p. 14). Wiener describes the process of making predictions,

> Assuming the statistics of a time series, it became possible to derive an explicit expression for the mean square error of prediction by a given technique and for a given lead. Once we had this, we could translate the problem of optimum prediction to the determination of a specific operator which should reduce to a minimum a specific positive quantity dependent on this operator. Minimization problems of this type belong to a recognized branch of mathematics, the calculus of variations, and this branch has a recognized technique. With the aid of this technique, we were able to obtain an explicit best solution of the problem of predicting the future of a time series, given its statistical nature, and even further, to achieve a physical realization of this solution by a constructible apparatus (Wiener, 1948/2019, p. 15).

Here the integration of control and communication, or in Wiener's term, cybernetics, does not only solve a problem in the face of chance and "achieve a physical realization" of the solution, but also produces scientific knowledge based on "a recognized branch of mathematics." The formation of cybernetics as such unsettles the concept *epistêmê* proposed by Aristotle and Plato and collapses the long-held distinction between *epistêmê* and *tekhnê.* In fact, Wiener is quite aware that an epistemological turn is epitomized in this cybernetic solution of prediction, which he mentions as "a completely new aspect" of engineering design,

> In general, engineering design has been held to be an art rather than a science. By reducing a problem of this sort to a minimization principle, we had established the subject on a far more scientific basis. It occurred to us that this was not an isolated case, but that there was a whole region of engineering work in which similar design problems could be solved by the methods of the calculus of variations (Wiener, 1948/2019, p. 15).

What, then, is the epistemological turn, which Leibniz's universal symbolism and calculus of reasoning, biology's theory of evolution, statistical mechanics, and cybernetics are all grounded in and contribute to?

2.5.2 Cybernetics as the Continuation and Culmination of Modernization

First and foremost, I would like to put forward a central claim that cybernetics is the continuation and culmination of the onto-epistemological movement in which the mind transcends the body and acquires the knowledge of the body through probability and statistics. To illustrate this view, it is worthwhile to check Collingwood's (1945) historical studies on the idea of nature, which engage with a "very far-reaching" question, "under what conditions is knowledge possible?" (p. 11) Laying out the Greek vitalist thought of nature, the Renaissance mechanical view of nature, and the modernist evolutionary perspective on nature, Collingwood has mapped the changing contours of natural science and knowledge. For ancient Greeks, nature is "not only a vast animal with a 'soul' or life of its own, but a rational animal with a 'mind' of its own" (p. 3). Nature's "soul" or vitality accounts for the ceaseless motions taking place within it, while its "mind" is the source of the regularity or orderliness of such motions. Upon the conception of "mind," "in all its manifestations, whether in human affairs or elsewhere, as a ruler, a dominating or regulating element, imposing order first upon itself and then upon anything belonging to it" (p. 3), the knowledge of "mind" turns into the basis of the knowledge of nature. However, as Greek philosophers shared the commonsense that "nothing is knowable unless it is unchanging" (p. 11) from Socrates' time onwards, they saw the knowledge of "mind" impossible unless mind is left untouched by bodily changes. Inherent in this quest for constancy and orderliness is the tendency to separate mind from body, which is against the Greeks' intuition that "first and foremost mind [is] *in* nature [emphasis original]" (p. 6). Therefore, when it came to the theories of knowledge, the Greek philosophers "found themselves obliged to recognize mind as transcending body"[5] and were "puzzled to know how this can be" (p. 6).

The paradox that the Greeks are trapped in also bothers the Renaissance thinkers in the sixteenth and seventeenth centuries, who struggled to find the connection between mind and body upon acknowledging the transcendence of mind from body. Based on a belief in a Christian God and the daily experience of making and using machines, the instinctive way of thinking about nature in Renaissance is mechanical: Nature is nothing but "God's handiwork" (Collingwood, 1945, p. 9). As such, nature is not a self-conscious organism that orders its own movements rationally but a machine "in the literal and proper sense of the word" that is designed, assembled, and put to operation for a certain purpose by "an intelligent mind outside itself:" "the divine creator and ruler of nature" (Collingwood, 1945, p. 5). Here mind and body are coordinated in the way that God, the transcendental mind, creates and rules the composition of bodily parts called nature. To know nature, then, is to access God's eternity lying behind the ever-changing natural phenomena.

But how to know the truth of nature? Unlike medieval scholars who resorted to ancient texts to make sense of nature, Renaissance scholars weighed the truthfulness of knowledge based on their machine-conditioned sensory experiences. With lenses to see, tools to measure, and machines to master nature, they were able to seek the "changeless something" hidden in nature through observation and experiments[6]. The body-based method forces Renaissance literature to develop a vocabulary of "body," i.e., that of "materialism," which asks what the thing is, along with a vocabulary of "mind," i.e., that of "idealism," which asks how "unchanging relations between the changeables" makes the thing as is (Collingwood, 1945, p. 12). For instance, Baruch Spinoza (1632-1677) believes that nature is knowable in terms of its two "attributes," one is "extension," "the intelligible 'extension' of geometry which Descartes had identified with 'matter'," and the other is “thought,” “not the mental activity of thinking but the ‘laws of nature’ which are the objects of the natural scientist’s thinking” (Collingwood, 1945, p. 12). Being a materialist and idealist at once, Spinoza is able to explain mind-body relations and address the problem of knowledge. However, not everyone takes the same stance Spinoza has, and Collingwood shows other efforts to delineate the distinction and connection between mind and body (also known as form and content, thought and extension, or spirit and matter). He mentions René Descartes (1596-1650), who is so desperate to find mind-body connections besides God that he assigned an otherwise useless organ, the pineal gland, the mission of uniting body and soul (Collingwood, 1945, p. 6), and John Locke (1632-1704), who denies the possibility of the “science of Substance” and maintains “the sufficiency of the ‘idealist’ answer” (Collingwood, 1945, p. 12). Short of God, nothing underwrites the unity of mind and body, and God Himself alone does not suffice the need to mediate mind and body. As a result, in pursuit of the “changeless something,” materialism and idealism “revealed themselves gradually in the eighteenth century as rivals” (Collingwood, 1945, p. 12).

The controversy between materialism and idealism no longer makes any sense in modern natural science, which, according to Collingwood (1945), has been established with reference to the paradigm of historical studies centered on “the conception of process, change, development” (p. 10) and has been gaining weight to the present day ever since the end of the eighteenth century. The recognition that nothing unchanging lies behind and determines the vicissitudes of human affairs poses challenges to historians who are meant to think “scientifically.” They eventually figured out “a progressive inquiry in which conclusions are solidly and demonstratively established,” and thus “proved by experiment that scientific knowledge was possible concerning objects that were constantly changing” (Collingwood, 1945, p. 13). The idea of “progress” gradually made its way into the terms of natural science in the 1800s and became famous as that of "evolution" around 1850s (Collingwood, 1945, p. 10), marked by the publication of Charles Darwin's book *On the Origin of Species* in 1859. At that point, the basic ontological, and the subsequent epistemological, questions bothering Renaissance thinkers were getting resolved, because the theory of evolution explains the gradual transition from inorganic to organic, from preformed to self-organized, and from body to mind without recourse to God. Instead of God, it relies on the historical process, or irreversible time, as the basis of existence and knowledge: "the species of living organisms are not a fixed repertory of permanent types but begin to exist and cease to exist in *time* [emphasis added]" (Collingwood, 1945, p. 10). As such, nature is not considered mechanical anymore, because a machine is a finished product and cannot evolve in time. Natural science started to replace descriptions of substance or "form" with that of function, indicating it is function that presupposes structure rather than the other way around. To demonstrate how this change of the object of knowing leads to that of the method of knowing, Collingwood reinterprets Zeno's famous paradox of the arrow, which reaches a strange conclusion that the flying arrow is at rest since it is at rest at every instant of its flight:

> The arrow is…composed of minute particles which move incessantly…These particles are themselves composed of particles still more minute, moving again in ways of their own. However far the physicist can push his analysis, he never arrives at particles which are at rest, and never at particles which behave in exactly the same way as that which they compose. Nor does he think of any one of them, at any stage, as behaving in exactly the same way as any other: on the contrary, the 'laws' according to which he thinks of them as moving are, in his own phrase,

> ‘statistical laws,’ descriptive of their average behavior in the mass, not of their individual behavior when taken separately (p. 21).

In other words, when the object of knowing turns into function, process, change, or development, knowledge becomes patterns of the specific function, process, change, or development across a certain lapse of time. Accordingly, the method of knowing should enable and facilitate the quest for such patterns, which is most well studied by two branches of mathematics, probability (the study of chance) and statistics (the practice and science of collecting and analyzing numerical data in large quantities).

So far, if we string together Collingwood’s historical studies on nature and the intellectual movements that Wiener believes to make possible cybernetics, i.e., Leibniz’s universal symbolism and calculus of reasoning, the theory of evolution, and statistical mechanics, it is clear that cybernetics is but an effort to “to resolve the very ancient dualism between changing and unchanging elements…by maintaining that what had hitherto been regarded as unchanging was itself in reality subject to change” (Collingwood, 1945, p. 10). Change at the bottom of everything must be tamed for the sake of knowledge and knowing, and historically this task would not have been accomplished without recourse to, first, the representation of constant change by numbers (Leibniz’s symbolism); second, the depersonalization of reason as calculation of numbers (Leibniz’s calculus of reasoning); and third, the integration of chance into the territory of the “hard science” like mathematics and physics (statistical mechanics). At this point the vocabularies of materialism and idealism become outdated, but the dichotomy between mind and body does not, because mind transcends body even further than it does in Renaissance contexts, to the extent that it takes the numerical representation of body *as* body. A paradigm shift of knowledge and knowing occurs subsequently: On the one hand, the Aristotelian and Platonic *epistêmê* becomes baseless as there are no "forms" or "the kind of things whose originative causes are invariable" (Aristotle, 1999, p. 91). On the other hand, constant change and perpetual motion can and must be calculated and controlled mathematically.

Cybernetics is the continuation and culmination of this onto-epistemological movement. Being aware of its intellectual heritages, cybernetics carries on the project of structuring the ever-changing world through statistics and probability. Although at times it was consigned to the dark corner of the academic landscape, it has obtained incomparable achievements. As a "science," cybernetics communicates to other sciences a metaphysical research program that reconciles changing and unchanging. At the same time as an "art," it manages constant change in real life by designing and making self-organizing apparatuses. It means to craft a comprehensive review of historical discourses and to launch a new era in which the program of control and communication matters more than the physical substrate that realizes the program. And it has succeeded in both aspects: cybernetics gives birth to or remaps the various sciences and engineering that make up the current "information" society. Dupuy (2009) comments, "The history of cybernetics is undeniably fascinating. Its ambition was unprecedented, the minds who animated it were among the most exceptional of their time, and its heritage was rich and varied" (p. vi).

Second, I want to demonstrate that the onto-epistemological movement of mathematizing the ever-changing world, which cybernetics is grounded in, is also the movement that founds so-called modernity and enables Man/human split. Modern thought and practice arose during the late 19th and early 20th centuries to make sense of the rise of secularization in 19th century Europe (Chadwick, 1975) and the newly emerging technique of "weak currents" in the 20th century, which uses "currents of any size whatever" to transmit signals (Wiener, 1948/2019, p. 56). According to Chadwick (1975), the secularization of European culture during the industrial revolution and shortly afterwards is a complex process where the transition to steam power and waterpower, the establishment of the mechanized factory system, the growth of big cities, and the development of a cheap press converge with the burgeoning of evolutionary social and natural sciences, and with the increasing conflict between science and religion. Upon the erosion of the Church's power, there arose humanism, a stance that emphasizes the agency of human beings and investigates human nature, human essence, or the constants of the human mind. In Foucault's (1989, 1996) terms[7], left by the death of God there is a space for abundant reflections on moral and political systems, on forms of knowledge, on nature, on order, etc., and herein emerges "a strange figure of knowledge" (1989, p. xxvi) called the human.

In fact, Foucault (1989) specifies "two great discontinuities in the *episteme* of Western culture: the first inaugurates the Classical age (roughly half-way through the seventeenth century)" (p. xxiv, emphasis in original), in which numerals began to predominate theories of knowledge, as exemplified by Leibniz's universal symbolism, and "the second, at the beginning of the nineteenth century, marks the beginning of the modern age" (p. xxiv), in which a rational human became the object and interpreter of knowledge. Modernization is a movement where, first, mind transcends body and puts body under its command with recourse to probability and statistics, and second, humanist man replaces the God and becomes the incarnation of the mind, the only knowing subject, which objectifies the rest of the world. As "origin and foundation of Knowledge (*savoir*), of Liberty, of Language and History" (Foucault, 1996, p. 61, capital in original), Man, despite its provinciality, gets universalized, and Man's historical bearings—religious, economical, bodily, linguistical, and so on—give rise to a full range of conceptions that are used to measure and judge people. Wynter (2015) has explicitly drawn on cybernetics, especially its concept "autopoiesis" (self-production), to diagnose the transition from Christian to Man1 to Man2. As the neurologicalrhetorical hybrid, human beings are autopoietic systems both in terms of their biological processes (DNA molecules as the replicators) and of their narrative productions of "truth" and "knowledge" (rhetorical statements, such as religiosity, race, gender, class, ability, as the sociogenic replicator codes). These sociogenic replicator codes activate neurochemical reactions (reward/punishment) in the brain, and, through the positive/negative feedback, Man and its onto-epistemological divisions sustain and regenerate themselves between "full human" on the symbolic side of life ("the name of what is good") and "other-or-less-than-human" on the symbolic side of death ("the name of what is evil"). Wynter proposes that such self-inscribing systems of human differentiation can be changed only by denaturalizing the sociogenic replicator codes, "we humans no longer need the illusions of our hitherto story-telling, extra-human projection of that Agency" (Wynter, 2015, p. 245).

So far, this section has discussed how cybernetics is the continuation and culmination of the onto-epistemological movement that founds modernity and enables the Man/human split. As chapter 1 has elaborated how digitalization brings about a functionalist, utilitarian orientation to Man and the space prescribed by Man, the following section will explore the coming of the Cyber-age: How cybernetics, despite its ups and downs within academic landscapes, eventually leads to the socio-technological movement of digitalization and becomes "a common vocabulary" of modern disciplines, including education.

2.5.3 The Coming of the Cyber-age and Cybernetics as the Unconscious of Modern Education

The Macy Conferences on cybernetics, a series of meetings sponsored by the Josiah Macy, Jr. Foundation and held between 1946 and 1953, aimed to restore a common ground to a variety of sciences, including biology, cognitive science, neurology, linguistics, anthropology, economics, ecology, computer science, etc., and constituted a landmark for a cohesive theory and technique of cybernetics. However, the heyday of cybernetics did not last long in the United States: In the 1960s academics started to draw sharp boundaries between cybernetics and their specialties. The reasons, based on Ronald Kline's (2015) historical studies on cybernetics, are, first, the over/misuse of the term "cybernetics" within and beyond formal academic conversations— "too much loose talk," "sloppy thinking," (p. 181) and amateur enthusiasm—had accumulated disrepute around it; second, the integration of cybernetic thinking into different disciplines had led to the fragmentation and invisibility of cybernetics; and third, the embrace of cybernetics by the Soviet Union in the late 1950s had created suspicions in Cold War America. It turns out that by the 1970s cybernetics had failed to survive as a universal science and technique applicable to problems in all fields (Kline, 2015, p. 199).

But cybernetics did not disappear; it lived on in the 1960s and 1970s as a specialty housed within three professional societies: "as second-order cybernetics in the American Society for Cybernetics; as part of general systems theory in the Society for General Systems Research, and as the field dealing with biological and social systems in the [Institute of Electrical and Electronics Engineering] IEEE's Society on Systems, Man, and Cybernetics" (Kline, 2015, p. 199). The reinvention of cybernetics, first, resulted in second-order cybernetics, or the cybernetics of cybernetics, in which the cybernetics of observed systems is subjected to a cybernetic understanding and critique of the observer. Second-order cybernetics considers the circular relationship between the observer and the observed rather than disguises or neutralizes the observer's perspectives and purposes, thus introducing a relativist epistemology: "perception should not be viewed as a grasping of external reality, but rather as the specification of one" (Maturana and Varlea, 1980, p. 85, as cited in Kline, 2015, p. 197). Second, cybernetics became integrated into general systems theory, which handles different kinds of organizations in the diverse world ("system") and laws independent from specific domains but governing such organizations ("general"). As "a watchword in the 1960s" (Brick, 2001, p. 124, as cited in Kline, 2015, p. 192), general systems theory approaches a system in its totality by unifying the interaction between its elements. The incorporation of cybernetics allows general systems theory to focus on highly complex "natural" systems, i.e., "biological, behavioral, sociological, political, legal, and economic systems" (Rowe, 1965, p. 2, as cited in Kline, p. 191). Third, cybernetics was turned into a science for analyzing biological and social problems, and as such it endowed biology and the social sciences with scienticity and accuracy. As Denis Gabor comments,

> With this extension [of cybernetics into the social sciences], we are now justified in considering cybernetics as deserving first priority among all the hard sciences. It may have come just in time to harden the regrettably soft social sciences and to save our free industrial society from the twin dangers of drifting into anarchy by its instabilities, or stiffening into a totalitarian system (Gabor, 1971, pp. 1-2, as cited in Kline, 2015, pp. 191-192)

Meanwhile, influential mass media raised public awareness about cybernetics by associating it with the budding personal computer. The prototype of the modern computer came into being in 1964, and, as a response, in 1965, *Time* magazine made "the computer in society" its cover story, referred to cybernetics as the "science of computers," and declared every generation since 1965 "the cybernated generation" (*Time,* April 2, 1965). The 1970s and 1980s witnessed the personal computer's coming of age and there was a surge of the English lexicon bearing the prefix "cyber-." Bruce Bethke coined "cyberpunk" to title his 1983 Si-Fi novel, describing the rebellious, lawless culture ("punk") of an oppressed society ruled by computers ("cyber"). "Cyberpunk" quickly became solidified as a subgenre of literature and artwork that focuses on a "combination of lowlife and high tech" (Sterling, 1986, p. xiv) within a dystopian setting. Influential works falling within this genre, to list a few, include William Gibson's novel *Neuromancer* (1984) that portrays "cyberspace," a consensual hallucination created by millions of connected computers, Ridley Scott's movie *Blade Runner* (1982) that examines humanity against the backdrop of the techno-oligarchy, and Katsuhiro Otomo's manga series *Akira* (1982-1990) that envisions youth alienation and disastrous consequences of biomedical power in a post-apocalyptic and futuristic "Neo-Tokyo." The invention and commercialization of the Internet in the first half of the 1990s spurred the use of cyber-words. Fischer (1998) analyzes neologisms in English based on a corpus consisting of data from the national English newspaper *The Guardian* between the years 1990-1996, showing that the numbers of cyber-words doubled each year from 1992 to 1995 (1996 still saw an increase but not that steep). In 1997, the U.S. President's Commission on Critical Infrastructure Protection (President's Commission, 1997) made up the term "cyber attack" to describe the electronic threat emanating from information networks, indicating that the "cyber-" form had been firmly planted into not only colloquial but also institutional usage. A more updated manifestation of the proliferation of cyber-words from the 1990s onward can be attained by using Google Books Ngram Viewer (Google Ngram), which charts word frequencies from Google's corpus of books and allows for the examination of cultural changes. The following graph shows how "cyber" has occurred in Google's corpus of books written in English from 1948 to 2019:

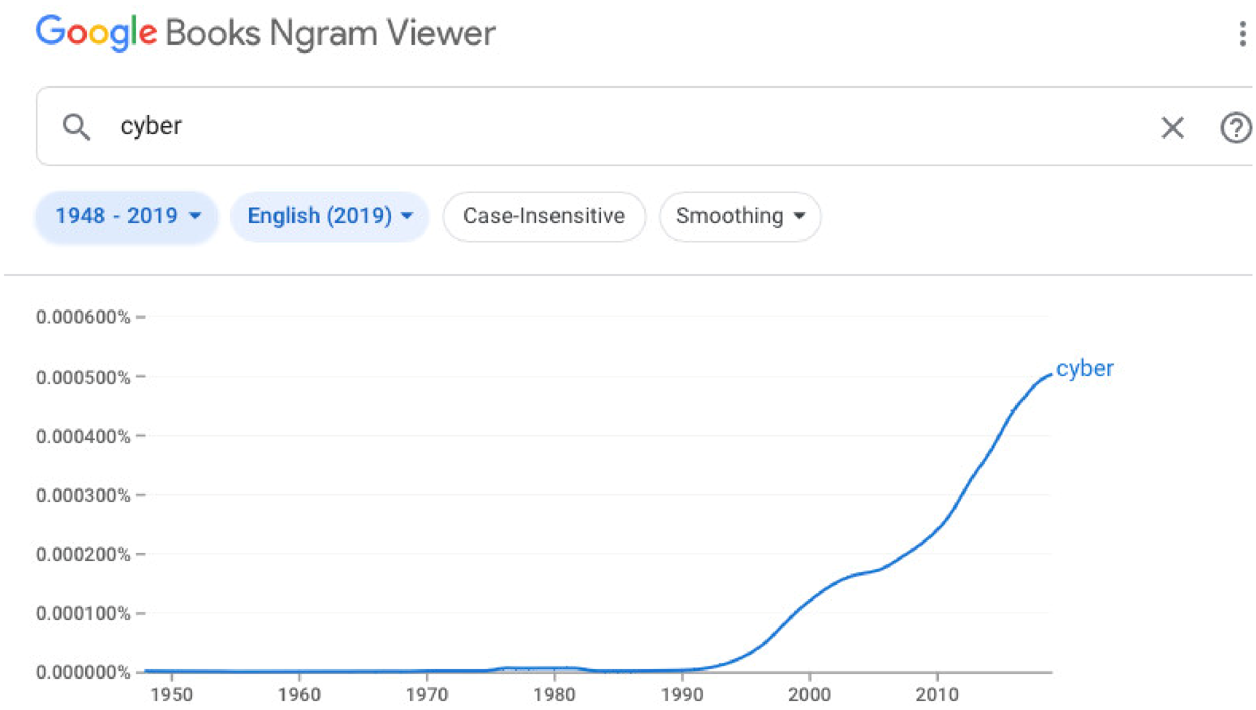

Figure. Ngram of “cyber” from 1948 to 2019

At first sight, it is the flexibility of “cyber” that allows people to use it everywhere: Seldom it seems does anyone have a clear and exact idea of what “cyber” means, but, generally, its public uses recognized its capacity to add to any old-fashioned terms a “modern,” “high-tech,” and “cool” touch. If we take a closer look at the establishment of modernity, however, we will find the mania for “cyber” was seemingly meant to happen, as cybernetics is the continuation, culmination, and the most recent update of an onto-epistemological movement to tame contingency and change through probability and statistics.

More than seventy years ago, Wiener (1948/2019) blueprinted how cybernetics would become “a common vocabulary” (p. 23) of fields significantly influencing our current life. Cybernetic understanding of computing machines based on the scale of two (“binary digits”) and the built-in logical decisions (Wiener, 1948/2019, pp. 7-8) basically capture the gist of what we call "digitalization." The analogy between the "all-or-none character of the discharge of the neurons" and "the single choice made in determining a digit on the binary scale" grounds neurophysiology and the design of artificial memory (Wiener, 1948/2019, p. 21). Also, the systemic approaches help uncover the psychological mechanism of "the perception of *Gestalt*, or of the perpetual formation of universals" (Wiener, 1948/2019, p. 27). Modern education is not an exception, although the importance of cybernetics for education has long been understated. Ideas central to cybernetics, i.e., control and communication, when translated into the language native to educators, assume that first, learning is more about the co-adaption between the learner and his/her learning environment, than about the learner's attainment of the external, static, and preexisting truth, and second, the goal, method, and effect of learning can be mathematically calculated and "scientifically" controlled. Cybernetics especially speaks to modern education's orientation to "human engineering" on a mass scale and at a reasonable price, for cybernetics adapts a reductionist method to detour the messiness of real life. Having cybernetic thinking as its unconscious, modern education has been preparing for the digital turn, the most influential realization of cybernetics, for decades.

2.6 CONCLUSION

Chapter 1 discussed how educational problems and issues regarding digitalization are understood in relation to Man and the Newtonian, container-like space. Chapter 2 meant to contextualize this kind of problems and issues in/as a concrete context, "STEM education" in the U.S. Without assuming what "STEM education" is, chapter 2 delineated the "unconscious" framework that makes possible its formation. One such framework is Descartes and Kant's philosophies of science, and another is the educational discourse of "dystopia" formed through an assembly of educational policies. Descartes and Kant's philosophies of science set Reason as the foundation of “modern” science and STEM education, and the discourse of “dystopia” depicts a cataclysmic decline in “democratic” society when human fails to ascend to Man through STEM education. This chapter then linked the unfulfilled promises of STEM education to the making of Man, the container-like space where every actor competes for room of survival, and the linear time flow along which a destination is preset. It showed that STEM educational systems end up reproducing the “Man-overrepresenting-human” problem rather than solving it. This chapter also locates cybernetics within the onto-epistemological movement of modernization, from which Man and modern human sciences arise, to set the stage for the next chapter’s illumination that STEM education is an outgrowth of digitalization. Chapter 3 lays out rends in digitalization, which intertwine with the philosophies of science by Descartes and Kant and the educational discourse of “dystopia” to enable “STEM education” to form. Chapter 3 also illustrates how Deleuze’s theory of “subject-space” helps disrupt the making of Man and Man-linked space through a specific case study that traces the movement of STEM discourses between the US and Chin

NOTES

1. Vallée (2009) specifies how Plato's metaphorical use of *kubernetike* (meaning "steering") as the art of governance has been mobilized in different linguistic contexts prior to Wiener's coining-up of the English word "cybernetics." For example, the French scientist André-Marie Ampère (1834) suggested "cybernétique" for the scientific study of politics, and S. Trentowski (1843) proposed "kibernetiki" as a new Polish word in his book *Stosunek filozofii do cybernetyki, czyli sztuki rządzenia narodem* (*The Relation of Philosophy to cybernetics, or the Art of Governing a Nation*). Though Wiener himself had not recognized Ampère's creation of "cybernétique" (Conway and Siegelman, 2006), he did associate, via discussions about "a purely mechanical feedback system… [i.e.,] that of the governor of a steam engine" (Wiener, 1948/2019, p. 132), his "cybernetics" with "governor" and *kubernētēs*/*χυβερνήτης*.

2. Please note that "scientific" used by Aristotle does not connotate what features the present "scientific" methodology, such as objective observation, experiment, verification or testing, and so on. By "scientific" Aristotle refers to what relates to forms or the essence of things. Such a transition of "science" is inseparable from the paradigm shift of epistemology, which is to be discussed in the following sections.

3. It is difficult, if not impossible, to exhaust thoughts that are believed to be interwoven with cybernetics. For example, Vallée (2009) lists some of the theories connected to cybernetics: "systems theory introduced by L. von Bertalanffy, the synergetics of H. Haken, and the study of dissipative structures promoted by I. Prigogine" (p. 22). Here I just outline what Wiener mentions as key to the establishment and maturation of cybernetics.

4. The modern mathematics of chance can be dated back to the mid-17th century, when the French mathematicians Pierre de Fermat and Blaise Pascal communicated about a problem of games of chance. The application of inductive reasoning to the calculation of chance is first seen in the Swiss mathematician Jacob Bernoulli's work *The Art of Conjecturing* (1713/2006), where the author treats the ratios of possible outcomes as determined by past experience or *a posterior*, rather than based on preset rules or known *a priori*.

5. For instance, Socrates contrasts "the bodily mind of appetite and sense with the pure intellectual apprehension of the forms which is effected by the rational soul's wholly independent and self-contained activity without any help from the body," and Aristotle claims that the intellect or reason differs from sense in terms that it is both detached from the bodily organ and "not acted upon…by its proper objects" (Collingwood, 1945, p. 6).

6. Describing nature to reveal its "forms," i.e., categorizations of its "marvelous and mundane products," provides the foundation for knowledge of nature, as Ogilvie (2008) explains, "Unlike their medieval predecessors, Renaissance naturalists condemned the inaccurate or inadequate descriptions of the natural world that had been bequeathed from antiquity. The disparity between what they saw and what they read motivated careful investigation into the variety of the created world and promoted the development of new descriptions modeled after the old" (p. 6). Perhaps seen in Francis Bacon's *Novum Organum* "*New Method*" (1620/2012) is the best-known endeavor to substitute a "scientific" method that highlights observation, description, and cataloguing for the old ways of syllogism and reference to ancient authorities.

7. Being a religionist, Chadwick means to justify an unbiased treatment of creationist ideas as he believes both science and religion are contextually based and socially constructed. In that aspect, he has limited common ground with Foucault. However, his critique on the taken-for-granted-ness of humanism as a gauge of human status without considering the culture, language, technique, and society it is embedded in

resonates well with Foucault's archaeology of knowledge, which denounces humanism for its essentialized conception of human beings and its naïve belief in the liberation of human through the sciences of human.

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3. STEM Education as an Outgrowth of Digitalization and a Travelling Discourse: An Example of a STEM Class in a Chinese Middle School

> In 2019, the Event Horizon Telescope team gave the world the first glimpse of what a black hole actually looks like. But the image of a glowing, ring-shaped object that the group unveiled wasn't a conventional photograph. It was computed — a mathematical transformation of data captured by radio telescopes in the United States, Mexico, Chile, Spain and the South Pole. The team released the programming code it used to accomplish that feat alongside the articles that documented its findings, so the scientific community could see — and build on — what it had done.
>
> JEFFREY M. PERKEL,
>
> *Ten Computer Codes That Transforms Science*

3.1 INTRODUCTION

The Event Horizon Telescope team's publication of "the first glimpse of what a black hole actually looks like" demonstrates the normalization of the digitally mediated scientific research in our age: An image formed from data that are captured by machine (radio telescopes) and mathematically transformed by specific programming code serves as a reliable source from which "the scientific community could see — and build on — what [the research team] had done." In other words, the integration of machine perception and the computation, which allows for accessing information that was otherwise impossible, becomes a legitimate way of "doing" science and visualizing scientific findings. *Nature* (Perkel, 2021) polled groups of scientists to build up a list of software tools that have once-and-forever transformed what is called "science." For example, the "formula translation" language Fortran (1957) turns human-readable instructions into "fast, efficient machine code" and thus makes programming accessible "for the first time" to scientists who are not specialized in computers (p. 345). The fast Fourier transform (1965), a programming approach which simplifies the mathematical process of a "Fourier transform" through a recursive algorithm, makes possible the expression of "a cacophony of complex signals changing with time" as "a function of frequency" at a fast enough speed that complex calculations in "digital signal processing, image analysis, structural biology and more" could be done realistically (p. 345). The first computerized biological database which contains "the sequences, structures and similarities of 65 proteins" (1965) launches the ongoing expansion of "today's massive genome and protein databases" (p. 346). Mining these "public data sets," biologist are not only able to "test [a] specific hypothesis," but also to find "connections that might never have occurred to those who actually collected the data" (p. 346). And first appearing as an email autoresponder sending to its subscribers "daily lists of preprints, each associated with an article identifier," arXiv.org (1991) develops into a preprint powerhouse which attracts submissions to and downloads from its indefinitely retained science papers: Until 2021, it has offered its users across the world "some 1.8 million preprints—all available for free" (p. 348). Breaking out of "the privileged loop" that only a small group of academic elites had early access to preprints, ArXiv.org and other similar digital systems reroute the flow of those yet-to-be-sanctioned "scientific" discoveries, bring in the once-marginalized "scientific" actors, "Those lower in the food chain… researchers at non-elite institutions," and, by doing that, make "science" a different eco-system than it was before: "It"s gratifying to see a methodology, considered heterodox outside of the particle-physics community 30 years ago, now more generally viewed as obvious and natural" (p. 348).

The above examples are but part of Perkel's long list of "key pieces of code that have transformed research over the past few decades," and "no list like this can be definitive" (p. 345). Considering how "advances in programming and platforms sent [science] to new heights" (p. 345), the tautology that STEM education is the education of STEM has to be opened up to the paradigm shift in science through digitalization. Digital infrastructures not only blur the established boundaries between science, mathematics, engineering, and technology, like "genome sequencing would not be science…before the Human Genome Project began" but now "a large proportion of contemporary biology (particularly genomics) turns on the production of a product—namely, data" (Stevens, 2013, p. 72), they also promote dynamic, systemic, quantitative, and multidisciplinary methods/exercises to solve problems, as summarized by Li and Huang (2019),

> Firstly, research *contents* are being extended from equilibrium static states to dynamic structures and from local phenomena to system behavior; secondly, research *methods* have gradually shifted from qualitative analysis to quantitative prediction, from single discipline-based to transdisciplinarity-oriented, and from data processing to artificial intelligence; thirdly, research *domains* are moving from fragmented knowledge to integrated knowledge systems, from traditional theories to complexity sciences, from detail-focused to multiscale-associated, and from multilevel discipline-based study to the pursuit of universal principles (p. 1091).

Educational professionals are sensitive to the digitally driven paradigm shift in/as science and STEM education, which aims at tackling global challenges, and their awareness turns into appeals for revising the content, pedagogy, as well as goal of STEM education. This chapter will first enumerate the WHAT, HOW, and WHY of STEM education in the U.S. as an outgrowth of digitalization: What is to be conceptualized as the singular unit called "STEM education" under the weight of digitalization? How is STEM taught and learned? And why is STEM taught and learned? Finding that U.S. STEM education, with all its integration with digitalization, pays little attention to the ontological changes through digitalization, this chapter attempts to address the problem of subject making for U.S. STEM education. To do so, it examines what happens in "parallel" educational settings, i.e., STEM education in China. It checks the discursive formation of Chinese STEM education and explain why a conversation with a Chinese STEM project matters for educators in the U.S. Then it looks closely at the project itself, which is called the "Future City" project conducted at a renowned STEM middle school in Hangzhou, China, from a Deleuzian "subject-space" perspective. This chapter uses the case study to argue that by "othering" perception it is possible for STEM education to help students formulate/solve life problems and redefine themselves in the turmoil of digitalization without restoring the sovereignty of Man or submitting to the authority of algorithms.

3.2 DIGITALIZATION AS A MORE RECENT CONDTION OF POSSIBILITY FOR STEM EDUCATION IN THE U.S.: WHAT, HOW, AND WHY

3.2.1 The WHAT Question: The Integration of Computing into STEM Education

In 2013, *Time* magazine commemorated the 30th anniversary of its declaration that the personal computer is the "Machine of the Year" by republishing the famous 1983 issue announcing that in tablet computer form. Remaining *Time*'s first and only Machine of the Year throughout over 30 years, computers have fundamentally reshaped histories of humanity and are still leading human societies into unpredictable futures. Brynjolfsson and McAfee (2016) claim that digital technologies, which "have computer hardware, software, and networks at their core," are powering another socio-economic revolution, just as Watt's steam engine starts up the Industrial revolution: "we're at an inflection point—a point where the curve starts to bend a lot— because of computers. We are entering a second machine age" (p. 9). "First mechanical, then electro-mechanical, and eventually digital," computers transferred from "a job title" referring to humans, "usually women, who spent all day doing arithmetic and tabulating the results," to "symbols processors" (p. 16), which encode all kinds of information— "text, sounds, photos, video, data from instruments and sensors, and so on" — "as a stream of bits," bring such streams together to produce knowledge, and reproduce such knowledge at close-to-zero marginal cost (pp. 61-62). Computing, therefore, goes far beyond crunching numbers; It is about conceptualizing and measuring the rich details of the world numerically, and, revolutionarily, as bits: "The digitalization of just about everything" (p. 57).

Education policy makers and practitioners recognize the importance of incorporating computing in their agendas and practice. In 2018, the National Academies of Sciences, Engineering, and Medicine (NASEM) conducted a study on the current surge in undergraduate degree production and course enrollments in the field of computer science (CS). This surge keeps up with the conceptual reframing of CS and "computing," where CS is defined as "the study of computers and algorithmic processes, including the principles, their hardware and software designs, their applications, and their impact on society" (NASEM, 2018, p. 16) and computing as "all areas of computer science, all interdisciplinary areas computer scientists work in, and all fields using computer science or computational methods and principles to advance the field" (p. 17). The integration of computing in the STEM pipeline is evidenced by past booms in CS and the broader category of "computer and information science and support services" (CIS) undergraduate degree production in 1980s and early 2000s, which "coincided with the appearance of personal computers in the 1980s and the dot-com explosion in the late 1990s" (p. 2), together with the steep increase of the number of CS majors at US higher education institutions and of students who enrolled in all levels of CS courses from 2005 to 2016 (pp. 2-3).p

Computing is not only regarded as the content of a specific STEM subject but also as the basic structures and facilities that all STEM subjects make use of, "computing is pervasive, and its penetration is deep and growing in virtually all sectors of the economy, all academic disciplines, and all aspects of modern life" (p. 7). In 2016, President Obama announced his "Computer Science for All Initiative" (The White House, 2016), which aimed to advocate CS education for all students across the country. It means to provide $4 billion in funding for states and $100 million for districts in the forthcoming budget to increase access to K-12 CS, to support NSF and the Corporation for Community Service financially for CS teacher training, and to call on efforts from all sectors of society to get involved in the CS education enterprise. A close reading of its rationale reveals the changing landscape of STEM education in the context of digitalization,

> States and districts could use these funds to provide access to CS courses to every high school student within five years, create a progression of CS learning experiences in elementary and middle schools, and ensure additional support and resources for students traditionally underrepresented in STEM fields. Participating states and districts would also be encouraged to create plans for expanding overall access to rigorous STEM classes, utilizing CS as a catalyst for increased interest in STEM more broadly, and reducing course equity gaps for all students, including underrepresented groups such as minorities, girls, and youth from low-income families (The White House, 2016, p. 4).

It is legitimate for the federal government to make such a huge investment in teaching and learning CS, as the acquisition of CS subject-matter knowledge and the utilization of CS "as a catalyst" promoting "STEM more broadly" *should* be integral to K-12 STEM education yet have not been.

Obama's CS-for-All call is followed by multiple efforts to accentuate CS in/as STEM education. For instance, the National Survey of Science and Mathematics Education (NSSME) commissioned by NSF and conducted by Horizon Research Incorporation has been one of the few authoritative surveys on the status of K-12 science and mathematics education in the United States ever since 1977. In 2018, for the first time in history, the survey included CS as one of the subjects for interviews. They produced a report named the 2018 NSSME+, of which "the plus symbol reflects the study's added emphasis on computer science and engineering, two disciplines that are increasingly prominent in discussions about K–12 STEM education and college and career readiness" (Whiffen, 2017, n. p.). Another report, the *2019 State of Computer Science Education* (Code.org, ECEP, and CSTA, 2019), analyzes state policies that help make CS education fundamental and suggests an increasing attention to K-12 CS education: 19 states require all high schools to offer CS courses and 34 states have already set CS learning standards. In educational practice, Chicago Public School became the first school district which has 'adopted Computer Science as a high school graduation requirement [starting with the class of 2020], taking this significant step along the path towards systemic change" (Dettori et al., 2018, p. 406). Meanwhile, private and non-profit organizations are also active players in collaboration with public schools in this movement for computing and learning. The 2021 report *Cultivating Interest and Competences in Computing* (NASEM, 2021) discloses that,

> Many in-school initiatives for K–12 STEM+C have been funded and implemented by corporations (e.g., AT&T Aspire, Tata TCS goIT, Google Code Next, Cisco

> Networking Academy, and Microsoft TEALS). Code.org has developed a number of activities to expand access to computing opportunities in school (e.g., providing computer science curriculum, teacher professional development, and the Hour of Code campaign) (p. 10).

Computer would be the "Machine of the Year" every year since 1982 if *Times* kept on discussing this topic, so it is not difficult to understand the national enthusiasm, or even frenzy, of embracing computing as a way of learning, working, and living. STEM education addresses "the digitalization of just about everything" by making computing both a key subject and a glue which fastens S-T-E-M together and redefines STEM education experiences. How is the "fastening together" and "redefining" carried out pedagogically? The following text will check how STEM is taught with the facilitation of computer.

3.2.2 The HOW Question: Computational Thinking and Makerspaces

> For over a century, science, technology, engineering, and mathematics education have established and steadfastly defended their sovereign territory. It will take a lot more than a four-letter word to bring them together.
>
> MARK SANDERS, *STEM, STEM Education, and STEMmania*

For Sanders, failure to interconnect science, technology, engineering, and mathematics education accounts for the problem that STEM education seldom implies "something new and exciting in education": "the status quo educational practices," i.e., "the universal practice in American schools of disconnected science, mathematics, and technology education," "have monopolized the landscape for a century" (2009, p. 21). She and her colleague (Sanders & Wells, 2005; Sanders, 2009; Sanders, 2012; Wells, 2013) propose to embed "authentic" scientific or mathematical inquiry in the engineering or technology design challenge presented by real-world problems, "thereby promoting recall and learning transfer" (Sanders, 2009, p. 23). They name such a curricular and pedagogical approach "Integrative STEM Education," in the sense that science, technology, engineering, and mathematics education are integrated, formal (lab and classroom) and informal (real world) contexts integrated, problem-reformulation and problem-solving integrated, and knowledge consuming and knowledge constructing integrated.

Though not explicitly associated with Sanders or the term "Integrative STEM education," two ideas featuring the same "integrative" philosophies have been brought to public prominence to make changes to the didactic STEM pedagogy in the context of digitalization. One is "computational thinking" (CT), a term put forth by Wing, a computer scientist and an NSF officer, in a series of articles (2006, 2008, 2011, 2014, 2017) and two workshops supported by the National Research Council (NRC) of the National Academy of Sciences, as summarized by *Report of a Workshop on the Scope and Nature of Computational Thinking* (NRC, 2010) and *Report of a Workshop on the Pedagogical Aspects of Computational Thinking* (NRC, 2011). Starting with a general description that CT is a way of "solving problems, designing systems, and understanding human behavior that draws on concepts fundamental to computer science" (Wing, 2006, p. 34), Wing adds specifications and extensions about how CT gets popularized. For instance, CT is "a kind of analytical thinking" of which the essence is abstraction and automation (Wing, 2008, p. 3717); Application of CT in daily life includes pipelining, hash tagging, sorting, to list a few (Wing, 2011, pp. 3-4); CT benefits education since "starting with the use of abstractions," it will "enhance and reinforce intellectual skills, and thus can be transferred to any domain" (Wing, 2014, n. p.); And CT is "*the thought processes involved in formulating a problem and expressing its solution(s)* *in such a way that a computer—human or machine—can effectively carry out* [emphasis original]" (Wing, 2017, p. 8). CT has been mobilized in disparate studies of STEM education over the past few years, like CT in STEM teacher preparation and development (Günbatar and Bakırcı, 2019; Alegre et. al., 2020; Boulden, 2020), CT in relation to cognitive science (Città et. al., 2019), CT in K-12 STEM projects (Swanson, 2019; Lee, 2020; Chatzopoulos, 2020), philosophies of CT (Sengupta et. al., 2018), so on and so forth. Though the original landscape of CT mapped by Wing is changing with the blooming of diversified research, key points of Wing's position are still influential (Blikstein and Moghadam, 2019, p. 61): CT is the computing skill-and-mindset transferable to formulate and solve problems in fields other than CS.

Another concept that deeply informs STEM teaching and learning is "makerspaces," which was originally related to MAKE Magazine's advocacy of kids' tinkering spaces (Cavalcanti, 2013). The *MAKE* magazine, together with the Maker Faire (a gathering of do-it-yourself enthusiasts), showcase the blooming of a technology-based and engineering-oriented DIY culture which combines digital innovations such as 3D printing and robotics with more traditional activities of arts and crafts. This grass-root maker movement, "a response to and an outgrowth of digital culture" (The *Economist*, 2011, n. p.), has "caught the attention of many major players in the tech and corporate worlds" like Intel, AMD, Oracle, Ford, NASA, etc., (Bajaran, 2014, n. p.). It also gains its way into education: The White House claims that "America has always been a nation of tinkerers, inventers, and entrepreneurs" and it will always support "opportunities for students to learn about STEM through making" (The White House, 2016, n. p.). "Makerspaces" refers to "places where learners have the opportunity to explore their own interests, to tinker, create, invent, and build" (Fleming, 2015, p. 2) through a creative use of physical and digital tools and materials, or an "internet of physical things" (Hatch, 2014, p. 3). Nowadays, makerspaces exist in many forms around the world, such as hackerspaces, Fablabs (Fabrication Laboratories), mobile makerspaces, and so on, and has become well-accepted amongst STEM educational practitioners, as a report by the California Council on Science and Technology comments, “there is a natural tendency to link making to tech fluency and STEM subjects” (Lindsey & DeCillis, 2017, p. 11). A European Union report entitled *Makerspaces for Education and Training* (Riina et al., 2019) outlines three aspects that make makerspaces appealing to education,

> Firstly, making activities naturally combine disciplines that are traditionally taught separately; secondly, while exploring real world problems individuals acquire new knowledge and create meaning from the experience; and thirdly, due to informal ways of social interaction in makerspaces, a diversity of flexible learning arrangements are created, e.g. peer learning and mentoring, peer coaching (p. 7)

In other words, blurring the established boundaries between different disciplines, between learning and living, and between teacher and student, makerspaces show their great potential to foster themes deemed as valuable for the future, such as innovation, collaboration, and problem-solving. There has been considerable work done on the practical aspects of implementing makerspaces in STEM education, especially on makerspace logistics (Ortega, 2017; Bower et al., 2018; Strawhacker and Bers, 2018; Martinez, 2021; Walan, 2021), on teacher support and development (Blackleyet al., 2017; Lang et al., 2018), and on social equity (Barton, et al., 2017; Schön et al., 2018; Keune et al., 2019; Love et al., 2020; Nixon et al., 2021).

Until now, this part has reviewed the game-changing movements in STEM pedagogue when STEM education is digitalized: the “Integrative STEM education,” computational thinking, and makerspaces. It is too early to say that such movements have already beaten out the didactic methods of teaching and learning STEM, especially in formal educational settings, but as efforts to comply with the dramatic changes brought about by computers and computing, they are drawing more educators' attention. In the next part, this chapter will explore how STEM education modifies its goals in relation to digitalization.

3.2.3 The WHY Question: Economic Productivity, Brainpower, and Civic Participation

> We were once told it was only a matter of time that all routine jobs that can be reduced to logic and sequence would be automated and that we must therefore focus on non-routine, "creative" "knowledge" jobs as the source of new and sustainable employment. Now it seems that the obvious strategy is outdated and open to deep learning restructuring.
>
> MICHAEL A. PETERS,
>
> *Deep Learning, Education, and The Final Stage of Automation*

The main drivers of efforts to remap STEM education are changes in the labor market, in the quality called "intelligence," and in the civic life. When new forms of automation actualized by AI and robotics destabilize the traditional "creative" "knowledge" jobs (Peters, 2018), when services and products extend "from atoms to bits" "that move at the speed of light" (Negroponte, 1995), and when digital infrastructures called platforms turn natural, production, business, and social life processes into data that "embody a politics" (Srnicek, 2016), STEM education has to adjust its goals to demands posed by digital transformations.

The first goal of STEM education is to retain and increase economic productivity of the nation and its people by equipping every citizen with CS skills. The U.S. Bureau of Labor Statistics (BLS) estimates that "employment in computer and information technology occupations is projected to grow 11 percent from 2019 to 2029, much faster than the average for all occupations" and in 2020 the median annual wage for computer and information technology occupations was nearly double of that for all occupations (BLS, 2021). In President Obama's CS-for-All call, it is clearly stated that "providing access to CS is a critical step for ensuring that our nation remains competitive in the global economy and strengthens its cybersecurity" and as "an active and applied field of STEM learning," CS "gives students opportunities to be producers, not just consumers, in the digital economy" (The White House, 2016). The 2018 report *National Strategic Overview for Quantum Information Science* and the 2019 report *National Artificial Intelligence R&D Strategic Plan: 2019 Update* by the National Science and Technology Council (NSTC) also acknowledge the surging needs for workers in sectors like AI, CS, and data science.

The second goal of STEM education is to re-envision and boost brainpower as computational. The concept of "intelligence" has been so vehemently discomposed by the advent of AI and robotics that Wing (2006) proposes that "the thought processes" involved in formulating and solving real-world problems should be in a way that a computer could effectively carry out. Also, Peters (2018) examines how deep learning as a form of AI changes the meaning of "creative" and "knowledge" (jobs). Deep learning refers to a way that computers develop their "brainpower": Computers "learn from experience and understand the world in terms of a hierarchy of concepts, with each concept defined in terms of its relation to simpler concepts" (Goodfellow et al., 2016, as cited in Peters, 2018, p. 550). Since complicated concepts are built out of simpler ones, how fast and to what extent computers become "smart" depend on "the amount of available training data," "computer infrastructure (both hardware and software) for deep learning," and the amount of time spent on learning, instead of on "human operators" who "formally specify all of the knowledge the computer needs" (Goodfellow et al., 2016, as cited in Peters, 2018, p. 550). The fact that deep learning enables computers to improve their "intellectual" capacity with experience and data not only speeds up automation but also extends automation to more sophisticated jobs which require a learning component. Previously, these jobs were only open to human candidates, such as those in "libraries, research, teaching, law, and other tertiary sectors" (Peters, 2018, p. 552). Peters' view of "creative" and "knowledge" resonates with Brynjolfsson and McAfee's understanding of computerized "innovation" and "science work": "The new communities of minds and machines made possible by networked digital devices running an astonishing variety of software… foster recombinant innovation" (2016, pp. 77-78) and "digitization increases understanding…by making huge amounts of data readily accessible, and data are the lifeblood of science. By 'science' here, we mean the work of formulating theories and hypotheses, then evaluating them" (p. 65). Under these circumstances, STEM education means to help students develop a digital smartness, a human-machine intelligence, which allows them to survive as a "native" of the digital ecosystem.

The third goal of STEM education is to inform students of the impact of computing on society so that historically marginalized groups can effectively participate in civic issues. Digitalization is changing the social structure drastically, for instance, digital platforms "in fact embody a politics," setting "the rules of product and service development, as well as marketplace interactions" (Srnicek, 2016, pp. 46-47). Excluded from CS education, students, especially those who have been suffering from institutional inequalities, may lack an understanding of their rights and responsibilities in a computationally mediated society, and thus risk "being more easily manipulated as consumers, voters, and citizens, and more vulnerable to cybercrime… [and being] more likely to be on the sidelines of future societal change" (Blikstein and Moghadam, 2019, p. 64). The recent iteration of this agenda could be found, for instance, in President Obama's call for "democratization of the hardware and software tools" (The White House, 2016, p. 3), the *National Strategic Computing Initiative Update 2019* (NSTC, 2019), and the *Cultivating Interest and Competencies in Computing: Authentic Experiences and Design Factors* (NASEM, 2021).

Summary: The Rational Subject Reinscribed in Digitalization

This section has examined STEM education as an outgrowth of digitalization in terms of its content, pedagogue, and goals. Though STEM education itself is being transformed along all dimensions in order to prepare America and its citizens for the opportunities and challenges presented with digitalization, the "subject-space" it produces does not move beyond the frame of Man and that of the Newtonian, container-like space linked to Man. According to Wing (2006, 2008, 2011, 2014, 2017), the essence of computational thinking is abstraction, which crafts "layers" out of a complex problem and defines logic relations between layers, and automation, which mechanizes abstraction layers and their relations. These intellectual skills can be reinforced through practice and transferred to everyday life's general problem-solving. Here a subject "intrinsically capable of truth" (Foucault, 2005, p. 522) could cast a clear light of (computational) reason upon a variety of things without any change of the Self. Moreover, the predominant movement of "Makerspaces" in STEM education treats "space" as a stage where "material" and "digital" resources are collected and displayed, awaiting for the scrutiny of a maker. Also, adhering to Wynter's "descriptive statements of Man," STEM education defines qualities of "human" in a "liberal" "democratic" society as bio-economically and politically adapted to digitalization. Intellectually/mentally well-built to think "computationally," a "human" is capable of performing his duties as a "creative" worker and a responsible citizen, as Hatch Mark (2014) states in his famous book *The Maker Movement Manifesto: Rules for Innovation in the New World of Crafters, Hackers, and Tinkerers*, "Making is fundamental to what it means to be human. We must make, create, and express ourselves to feel whole. There is something unique about making physical things. Things we make are like little pieces of us and seem to embody portions of our soul" (p. 11).

Refining "reason" with computing but leaving the ontology/epistemology of the modern subject untouched, STEM education just reinscribes the culturally laden figure of Man in "the final stage of automation" (Peters, 2018). As an effect, the new descriptive statements of Man will layer upon existing inclusion/exclusion criteria, intertwining with them and evolving into new, tricky forms of "-isms." This is why Disessa (2018) criticizes the idea of transferring computational thinking to all domains of life and calls it "cultural imperialism": "why should we all have to adopt culturally specific conventions [of CS] … to inscribe a key idea?" (p. 26). To put it another way, he believes that the computational thinking skills are too discipline/culture-based and too partial to depict the fundamental shifts occurring through digitalization, which he ascribes to the computational *literacy*'s overshadowing of the algebra/calculus literacy. Noting that literacy is "a particular representational form for wide-spread learning, use, and subsequent value" (p. 8), he shows how the Galilean proof of "distance equals rate times time" is confined to the text-drawing literacy ("algebra in its modern form simply did not exist in Galileo's time' (p. 6)) and that it epitomizes an intellectual terrain and an ecology of learning activities other than those emerging from the algebra literacy. Therefore, when computational literacy, which is "logarithmically halfway between" the algebra/calculus literacy and the written-text literacy, gains predominance, shifts arise regarding "the basic intellectual structure of domains of knowledge along with learning trajectories and societal participation structures— who gets to do what" (p. 8): the remaking of the subject onto-epistemologically.

Now that the problem lies in STEM education's neglect of subjectivation through digitalization, it is time to check how Deleuze's theory of "subject-space" helps address this problem. In the Deleuzian model of perception and action ("perception-affect-action") (Deleuze, 1986), the subject is regarded as the "indeterminant center" ("affect") between its perception and action: When perception happens where and how it had in the past or it is prescribed to, action will always take place routinely and the subject will always get reproduced. The following story exemplifies what is meant by "othering" in "othering perception" and the necessity of "othering" perception in the making of a particular STEM worker, a medical doctor, in an age revolving around AI, robotics, and big data: How could "I" get constructed neither as Man, nor as an algorithmic by-product?

3.3 "OTHERIING" PERCEPTION: "TO BE HUMAN IS TO BE A HUMAN"

> Sharon Roman, a patient with multiple sclerosis, wrote that, "when the hands have become calloused and rough, the ears unhearing, and examinations start to feel like interrogations, it is time to reconsider" one"s choice of doctor.
>
> ERIC TOPOL, *Deep Medicine*

Deep medicine, according to Topol (2019), refers to the culmination of the process of digitalizing medicine, with AI brought into its heart. There are three "deep" components: "First is the ability to deeply define each individual (digitalizing the medical essence of a human being), using all relevant data" (p. 16); "Second is deep learning… [which] not only involve pattern recognition and machine learning that doctors use for diagnosis but a wide range of applications, such as virtual medical coaches" (p. 16); And "the third, and most important component is deep empathy and connections between patients and clinicians" (p. 17). The first two components are what computers are doing and could do better than current medicine, and the third is the unique contribution that humans make: "Deep empathy" and a close human-to-human relationship.

Medicine expects that AI could accurately and efficiently "synthesize notes and labs and imaging into something actionable" (p. 295) and thus "unshackle clinicians form electronic health records" (p. 288). Both doctors and patients will benefit from AI taking over this time/energy-consuming work: Doctors are likely to suffer less from burnout and have better job satisfaction, and patients are likely to retain more time with doctors, which "is linked with improved outcomes and … reduce[d] subsequent costs" (p, 286). Though at present AI is still "short on real-world, clinical proof of effectiveness," it will take hold of narrow tasks requiring algorithmic validation: "Workflow will improve for most clinicians…at the same time, [the] individual… will eventually gain the capacity to have their medical data seamless aggregated, updated, and processed to guide them" (p. 309).

Since computers will "progressively outperform humans for various narrow tasks" (p. 290), it is necessary to explicate why a "human" doctor is still worthwhile. Medicine treats "human" diseases; a knowledge of "human," first of all in an ontological sense, is the prerequisite of medical practices. What makes a human "human" in the digital era? "To be human is to be a human, a specific person with a life history and idiosyncrasy and point of view" (Christian, as citied in Potol, 2019, p. 290), an AI expert comments. Arising from the messiness of histories and everyday life are various modalities of perceiving, affecting, and acting, which could by no means be reduced to streams of bits. Curing should start from honoring each of these modalities, a job "human" doctors could do better than machines: "Notably, human empathy is not something machines can truly simulate" and "empathy is the backbone of the relationship with patients" (p. 290).

However, the cultivation of empathy, or being present with the patient, is not encouraged when medicine is regarded as a serious science conductible only through rationality, as Topol writes bitterly,

> Ironically, as doctors, we are trained to avoid the s-word [suffering] because it is not actionable. The *American Medical Association Manual of Style* says that we should "avoid describing persons as victims or with other emotional terms that suggest helplessness (afflicted with, suffering from, stricken with, maimed)." Thomas Lee, writing in the *New England Journal of Medicine*, argues that, although "human suffering can be considered (and preferably averted) in the abstract," it is important that "patients must simply "have a disease or complications or side effects rather than "suffer" or "suffer from" them" (p. 291)

Medical education as such sees a subject, the doctor, as "inherently capable of truth" and detached from its knowledge-acquiring process, and the making of a medical doctor as elevating a subject to a position where it could examine diseases with "the clear light of reason."

So restoring the modernist subject turns out to be no remedy for the "human" status disrupted and endangered by digitalization. What proves effective in becoming a "human" doctor when AI, robotics, and big data are making steady progress within medicine is to *other* perception, i.e., to perceive other than prescribed by algorithms or the established medical education "talk." For instance, students from Yale's medical school are required to take a course on the art of observation by spending time in an art museum. A review of the course reads, "my tool is the medical gaze, the desire to look for pathology and connection, and it would seem there was no opportunity for that within a pigmented square of uniform color or a rectangle of haphazard paint splashes. But in me a profound and inward sort of observations was taking form" (p. 297). "A pigmented square of uniform color or a rectangle of haphazard paint splashes" disrupts the "normal" routine of "the medical gaze" so that the subject is reformed: "in *me* a profound and inward sort of observations was taking form [emphasis added]" (p. 297). In a randomized trial of art training at the Philadelphia Museum of Art in 2017, a group of first-year medical students from the University of Pennsylvania demonstrated "remarkable" improvements of their skills in observing and describing medical images after "six 90-minutes sessions over three months" (p. 297). Concluding that "taking would-be physicians out of the hospital and into a museum—taking them out of their own world and into a different one—made them better physicians" (Epstein and Gladwell, as cited in Topol, 2019, p. 297), researchers point out how important it is to step out of one's "own world," the enclosed system that produces a certain kind of people through a regular procedure, into "a different one," where unexpected perceptions occur and add to the repertoire for the production of subject.

What does it mean to be a "human" doctor when AI, robotics, and big data seem to take over medicine? This should not be a problem only meaningful for Topol and his fellow medical professionals. Stakeholders of STEM education would benefit from extending this problem to STEM education in general: What does it mean to be a "human" STEM worker in the face of digitalization? In a broader sense, everyone experiencing the so-called second machine age might want to go over the existential puzzles embodied in this problem: What does it mean to be a "human" when the line between "human" and machine keeps blurring?

After carefully examining the status quo of medicine and medical education in digitalization, Topol gives his answer: "To be human is to be a human." The becoming-a-human does not orient towards a Man overrepresenting itself as human nor a mathematically calculated and algorithmically controlled digital "inhabitant." To be *a* human, your hands cannot be "calloused and rough," your ears cannot be "unhearing," and your gaze cannot be "interrogative"; By allowing perception to happen where and how it is not set to, the “subject,” as the “indeterminant center” between perception and action, becomes more receptive of “inputs” and thus more capable of “outputs”: It is of more versatility in terms of affecting and acting.

Topol’s work exemplifies how the subject-making in medicine is boosted by othering perception, and perception, as the spatial aspect of Deleuze’s “subject-space” complex, could serve as the worksite of subjectivation in the wider context of STEM education. The following section will approach the on-site dynamics of making “human” through nonlinear temporality and paralleling spatiality in a STEM project called “the Future City” at a middle school in Hangzhou, China, from a Deleuzian perspective. It will first explain why a “Chinese” STEM project is worth checking out for US educators and why a “Western” (Deleuzian) theory is used to introduce that project, and then it will dig into the curriculum and classroom activities.

3.4 EXPERIENCING THE *APORIA*: A “PARALLEL” STEM PROJECT IN CHINA

Just as art training helps medical students perceive the once imperceptible, the introduction of a STEM project occurring in China will offer a chance for educators in America to open up the rationale and practice of STEM education to a wider array of histories and knowledges so that the possibilities will no longer be constrained by the trope of Man and digital essentialization/manipulation. To be clear, “science” and “STEM education” in China are not imported from the “West” but emerge as a response to the dominant discourse of modern science out of immediate politics and local histories. Despite bearing the name of a “STEM” project, the “Chinese” case embodies a different rationale and thus is better regarded as “parallel” to its U.S. counterparts. Also, the Deleuzian theory of subjectivation is by no means “applied” to the STEM practice in China but serves as an interpreter through which the STEM education in America finds in *itself* “a profound and inward sort of observations … taking form” (Topol, 2019, p. 297). This section will expand these points one by one.

3.4.1 A Brief Review of STEM Education in China

Researchers who are conscious of the colonialist undertone of modern science discourse (Science is delivered from the “West” to the rest of the world) are “challenging the discursive construct…that relegates the non-West to the waiting room of history” (Amit Prasad, 2006, p. 220). For instance, in an ongoing series of books about the history of science and technology in ancient China called *Science and Civilization in China* (1954-now), Joseph Needham, a well-respected scientist who originally initiated and edited this encyclopedia, chooses not to delineate the idea of “science” in China by recklessly transporting the anglophone conceptualization. Rather, he keeps “science” open and socio-historically based, e.g., by opening his discussion of scientific thinking in Chinese “Middle Ages” via resorting to the remote and pictographic origins of key Chinese characters appearing in Taoist classics.

STEM education research in China also shows the continuous efforts to attribute locality to STEM thoughts and practices. The idea of STEM education was discussed at least as early as 2008 as part of a general review of U.S. higher education (Chen, 2008), but it remained a less-visited topic until the Ministry of Education of China released a document entitled *“Guiding Opinions on Further and Profoundly Advancing Education Informatization during the “13th Five-Year Plan” Period”* (the Ministry of Education of China [MOEC], 2015), which for the first time officially acknowledges STEAM education and makerspaces as “new educational modes” practicable at Chinese schools. This announcement ignited heated academic debates over STEM education thereafter, for instance, over the genealogy and power dynamics of STEM education in the U.S. (Yu and Hu, 2015; Zhao and Lu, 2016; Fan and Zhang, 2018; Zhao et al., 2018; Yu, 2018), over the curriculum and pedagogue of STEM education in specific educational settings in China (Wang, 2015; Fu, 2017; Zhou and Tan, 2018; Jin, 2018), over social equality in relation to STEM education (Yuan and Zhao, 2017; Zhao et al., 2018), and over the danger of "copying and pasting" the US framework of STEM education in the Chinese context (Dong, 2015; Zhao and Xu, 2016; Li et al., 2016; Chen, 2017). Recognizing that the so-called "STEM education" is imbued with historical traces variant from those constituting "China/Chinese," scholars take the reconstruction of STEM education as a chance to proliferate their ways of envisioning the world and making systemic changes.

What has truly brought STEM education beyond academia to intense public attention in China is the consecutive publication of Chinese STEM policies and policy reports since 2015. For example, the *13th Five-Year Plan of Education Informatization* (MOEC, 2016) sets the goal of education system reform as providing "networked, digitalized, individualized, and lifelong" education to all students, regardless of their age, socioeconomic background, and geographic location, through increased investments in digital infrastructures and data services, and pedagogical innovations such as makerspaces and STEAM learning. The *Elementary School Science Curriculum Standards for Compulsory Education* (MOEC, 2017a) conceptualizes "scientific competence" as the capacity of solving real-world problems and engaging in civic affairs through scientific methods. Seeing "scientific competence" as essential for the "comprehensive, coordinated and sustainable development of Chinese society" (p. 1), the *Standards* proposes an inquiry-based, student-centered, and integrative STEM curriculum that helps cultivate "scientific competence." The *High School Information and Communication Technology (ICT) Curriculum Standards* (MOEC, 2017b) advocates project-based learning driven by STEM education ideas so that "students could enjoy their research and creation activities at the same time when they develop the ICT skill and mindset" (p. 32). The *Education Informatization and Network Security Work Essentials in 2019* (MOEC, 2019) specifies goals and tasks in fields like AI in education, digital resources sharing, digital governance of education, teacher and student information literacy enhancement, data security, etc. STEAM is listed as one of the few kinds of projects (others include online learning space, MOOC, and intelligent adaptive learning) that the report plans to conduct in the "AI in education" demonstration areas.

At first sight, the U.S. and China seem to tell the same story about STEM education: It is all about the educational endeavor to secure the individual and social prosperity by helping students acquire STEM literacies. However, a close look reveals that the discourse of STEM education in China has "a regularity (an order)" "between objects, types of statement, concepts, or thematic choices" (Foucault, 1969/2013, p. 38) other than what thread the U.S. STEM "talks," namely, a dystopia where the humanist subject, Man, became non/less-than "human" if he was not enlightened enough to succeed in his competition with Others for living space. The "regularity" or "order" that forms the STEM discourse in China at present is a sense of cultural and historical belonging, as demonstrated by a fixed term used in all Chinese education policies and policy reports: "*With Chinese characteristics*." This term does not come out of thin air: Foreign invasion and colonialization since 1900s have once and forever scared the group of people who name themselves "Chinese," and, having long been treated as Man's Other, they fabricate an essentialized form of "human" which draws on historical resources "with Chinese characteristics" to confront Man's violence. For instance, the *Education Informatization 2.0 Action Plan* (MOEC, 2018) puts forth the guidelines of Chinese education informatization as follows, "…making education more open, more contextual, more humane, more egalitarian, and more sustainable…figuring out a way *with Chinese characteristics* to realize education informatization [emphasis added]" and "…offering Chinese wisdom and a Chinese approach to meeting the global challenges of education informatization." Within the paradigm of a "Chinese" man, "scientific competence" is rallied to destabilize, rather than to reinforce, the sovereignty of Man. Moreover, such a subject places itself in relation to Others in a different way than Man does: Rarely if ever is there any statement of Others as endangering the "human" status of a "Chinese" man and the real threats are believed to arise from within the subject, that is, its inability to adapt itself to chances and challenges brought forth by digitalization. The Chinese government's flagship education policy, *China's Education Modernization 2035* (The Communist Party of China Central Committee and the State Council, 2019), charges education with "an important mission" to "serve the great rejuvenation of the Chinese nation," meaning a "Chinese" man is struggling with disparities between a *me* at present and a *me* imagined out of histories, rather with the hostility between *me* and Others.

The making of a "Chinese" man as an alternative to Man is not without problems, as Abraham (2006) points out when he uncovers the fallacy of "Indian Science," "Postcolonial science studies need a proliferation of historical and sociological accounts of science as practice in order to set a standard against which we can more easily identify "Indian Science" as a discourse that shapes a political struggle that has little to do with science studies, even if it has much to do with India" (p. 210). But it is beyond the remit of this work to discuss how the construction of "Chinese" "shape[s] a political struggle that has little to do with science studies," since the purpose of reviewing Chinese STEM education is to set up the context for the case study and to explicate why the case, a STEM project called "The Future City" at a middle school in Hangzhou, China, offers a chance for STEM professionals in the U.S. to encounter Others or to "other" perception: Though bearing the name "STEM," this project is not sited in the framework of Man.

The U.S. STEM education will benefit from an encounter with Others. The following part will demonstrate what happens in such an encounter to justify the insertion of a "Chinese" STEM project in a work on the "U.S." STEM education and the use of a "Western" theory along with a "Eastern" practice, namely, puzzles of deconstructing an identity, border-crossing, and paralleling.

3.4.2 Deconstruction, Border-Crossing, and Paralleling

Deconstruction is by no means a negation, or a substitution, but a reconsideration of the relationship between *me* and Others. It is the crossing of the threshold of a particular "identity," which "puts us on the path…of the aporos or of the aporia" (Derrida, 1993, p.8), a state where we are destined to be trapped in the dilemma of "to pass/not-to-pass": on the one hand, as long as an "identity" is "finite [finie]" (p. 1) — "to be identified with X" means "to be confined to the territory of X," "a certain border crossing" will "not seem impossible" (pp. 1-2); on the other hand, as soon as X, as the totality that an "identity" encompasses, gets "overdetermined, or rather contaminated, by the events" of crossing, X is no longer what it is or what one thinks it is, that is, no longer "identifiable" or "d'terminable" (p.7), and the borders of X are therefore no longer stable, thus the crossing turns out impossible. Derrida has carefully described this aporia or this dilemma as

> The difficult or the impracticable, here the impossible passage, the refused, denied, or prohibited passage, indeed the non-passage, which can in fact be something else, the event of a coming or of a future advent [événement de venue ou d'avenir], which no longer has the form of the movement that consists in passing, traversing, or

> transiting. It would be the "coming to pass" of an event that would no longer have the form or the appearance of a pas: in sum, a coming without pas (p. 8).

Thus to deconstruct does not mean to solidify the borders to make the "impracticable or impossible" passage practicable or possible ("the supremacy of Man" or "the sovereignty of Chinese"), or to impose judgements which could not be made but must be made ("Applying a 'Deleuzian' theory to a 'Chinese' case"), nor to close the passage absolutely ("the 'Chinese' case does not make any sense for 'U.S.' education"); to deconstruct is to experience, to experience the experience of the aporia:

> (When someone suggests to you a solution for escaping an impasse, you can be almost sure that he is ceasing to understand, assuming that he had understood anything up to that point.) Let's ask: what takes place, what comes to pass with the aporia? Is it possible to undergo or to experience the aporia, the aporia as such? Is it then a question of the aporia as such? (pp. 32-33)

"To experience the aporia" means to parallel the Self with Others while at the same time making them speak to each other. Every attempt to cross the border of the Self pushes the border further away and makes it uncrossable, but it is the constant crossing of an uncrossable border that sets the Self to examine inwardly its historical makeups and to renew its "territory." To put it in the context of this work, it is impossible to negate or substitute historical complexities from which "U.S." or "China" arise, while "a coming without pas" helps both U.S. and Chinese STEM education stay vigorous, capable of formulating and handling problems in different ways.

Meanwhile, considering this work's focus on subject-making in digitalization, the radical theory of subjectivation proposed by Deleuze helps make the most of the experience of aporia, in terms of its extreme sensitivity about digitalization (see the "society of control" and the "Superfold/superman" in charge of animals, silicon, and codes), its strong determination to break the impasse of liberal democracy (see the "Capitalism and Schizophrenia" project), and its thorough familiarity with statements of the modernist subject (see the critique on Descartes and Kant). Deleuze's theory of subjectivation "paraphrases," rather than guides, the STEM project in China, so that "a coming without pas," or an interpretation of the uninterpretable, becomes more inspiring.

This section paves the way for the following case study by explicating the discursive formation of the Chinese STEM education and by justifying the encounter between "Chinese" and "U.S.." The next section will investigate a STEM project at a middle school in Hangzhou, China, which mobilizes historical texts, artifacts, and constructions in relation with "technoscience" to experiment subjectivation neither falling under the rubric of Man nor driven by digital essentialization and algorithmic prediction.

3.5 TIME TRAVEL AND PARALLEL UNIVERSES: THE FUTURE CITY PROJECT

The field research was carried out from May to July 2018, at Da Guan Middle School in Hangzhou, China. Founded in 1973, Da Guan Middle School is the largest public middle school in Gong Shu district with 145 teachers and over 1500 students divided into 35 classes in 2018 (Da Guan Education Group, 2020). As a public school, it accepts students from multiple elementary schools in the same district and advocates differentiated learning based on the diversity of its student body. Besides its strong academic reputation, this school is well-known for having pioneered the Chinese STEM education: It has started developing STEM curriculums and running regular STEM courses ever since 2004, way earlier than when STEM education was officially and systematically inaugurated in China. Now it is one of the 22 National Demonstration Schools of STEM education (evaluated by the Chinese STEM Education Association in 2017), one of the 79 National Leading Schools of STEM education (evaluated by the National Institute of Education Sciences of China in 2018), and one of 15 Zhejiang Province's Top-seeded Elementary and Secondary Schools of STEM education (evaluated by Zhejiang Province Education Department in 2017).

Daguan Middle School has a highly digitalized campus, partly because it is located in the silicon city Hangzhou, where the Chinese digital barons like Alibaba, Tencent, Tiktok, Huawei, etc., place their headquarters or important research centers/labs. Since 2005, all Daguan's classrooms have been equipped with multimedia facilities. Since 2014, an intelligent adaptive learning system has been adopted to record and analyze exam results of all students to profile and decode their academic trajectories and give them real-time explanations, advice, and exercises for maximum, personalized benefit. In 2015, a 54,000-square-feet building was completed for the new STEM center, which hosts multiple innovation labs including the virtual reality (VR) lab, the 3D print and laser cutter lab, the intelligent robotics lab, the future city design lab, so on and so forth. In the spring semester 2018, the following were offered as elective STEM courses, with each of them allowing 10 to 20 students to enroll: "The Ancient Tower and Local Culture," "Tea Culture," "Intelligent Robotics," "3D Innovations," "Aircraft and Marine Model," and "The Future City." The following text will examine the project-based learning course "The Future City" in terms of its making of subject from a Deleuzian "subject-space" perspective. The basic philosophy of this course is to set imaginary pasts and futures, which the everyday perception and action might not inspire, with the aid of multimedia and VR so that students develop new ways of formulating and solving problems "here and now." It consists of three mini projects: "Measuring and Mapping Your Campus," "Digitalization and An Age-Friendly City," and "A City and Ocean Symbiosis."

3.5.1 Measuring and Mapping Your Campus

This project introduces three ways of mapping through Chinese history in comparison to the currently predominant method of map-production, i.e., the integration of location data (where) with descriptive data (what is happening there) through digital hardware and software, as exemplified by the making of Google Maps.

One way of mapping in ancient China is to facilitate the local government's administration by placing the city (usually a county town) in the middle, drawing mountains and rivers around the city based on their relative locations and sizes, and then adding roads between the city and the nearby mountains/rivers. Below is a photograph used in the class to illustrate what this kind of map looks like (Fig. 1):

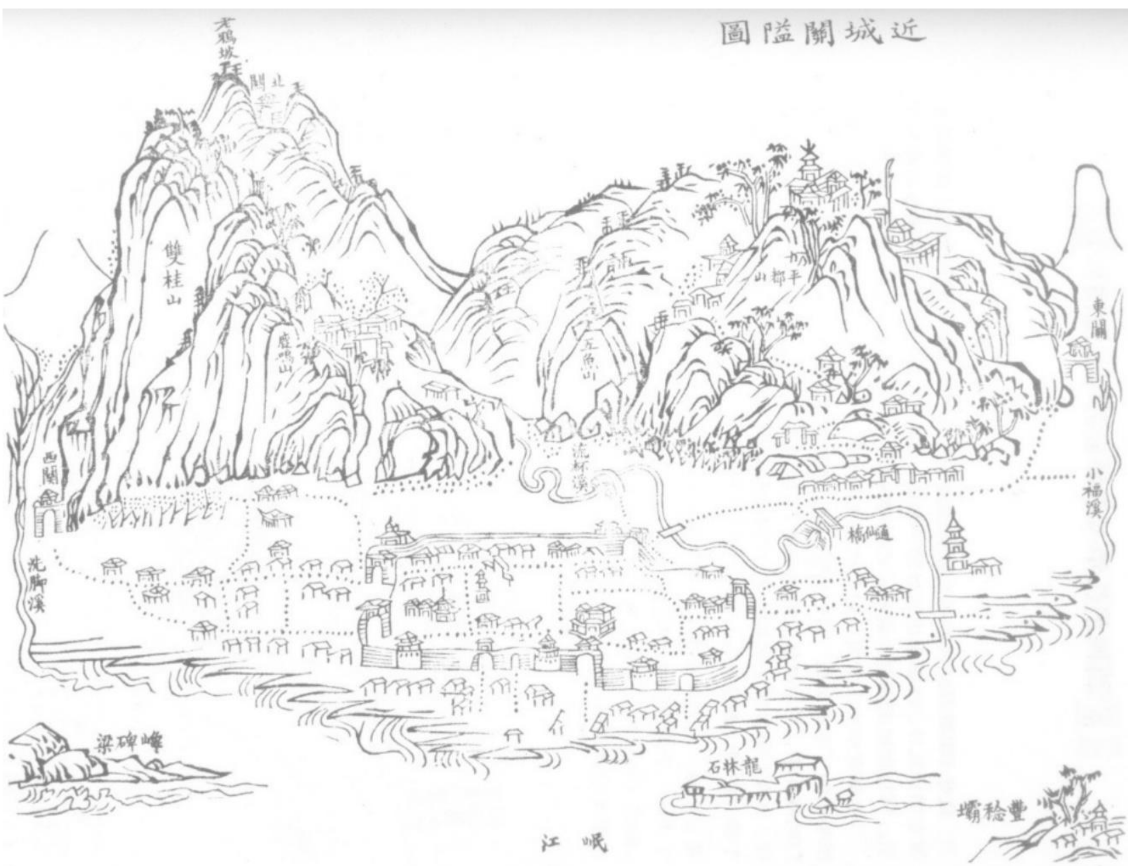

Figure 1. The Map of Jincheng Pass, Fengdu County (1869) (Chongqing Library, as cited in the curriculum of the project)

Another way of mapping serves the need of transportation and travelling since it uses the road, the waterway, or the ocean lane as the basis of map-making. It is also an artistic creation as it demonstrates the map-maker's painting skills and aesthetic sensibilities. Cartographers first draw the route followed by a cart or ship in the middle of the map, specify the starting point of their journey, and then travel along the route in person. They draw mountains and cities they pass by on the draft, sometimes putting notes explaining their impressions and experiences of a place (see sentences in red in Fig. 2). Finally, when they arrive at the destination, they add the destination and complete the map. The teacher gave students an example as follows (Fig. 2):

Figure 2. The Map of the Beijing-Hangzhou Grand Canal (1870s) (National Geomatics Center of China, as cited in the curriculum of the project)

A third way follows basic principles of mapping advanced by PEI Xiu (224-271), using scale, direction, road distance, slope angle, etc., to make maps "represent" the landscape accurately. With the square grid system and scale, this kind of map provides information necessary for military actions and administrative tasks. Here is the teacher's example (Fig. 3), which is a three feet squared map precisely pinpointing China's coastline and river systems with a graduated scale of 100 *li* (a Chinese unit of length which varied through time, 1 *li* = 415-576 meters) for each grid,

Figure 3. The Yu Ji Tu/Map of the Tracks of Yu Gong (1137) (Carved Stone in the Stele Forest of Xi'an, as cited in the curriculum of the project)

Such a grid system would not be possible if the effective measuring tool, *Ji Li Gu Che*, was not invented. *Ji Li Gu Che*, literally translated as "mileage drum wagon," is a horse-drawn, two-wheeled, and double-decker cart which positions puppets on both layers. Wheels are connected to a set of gears which drives puppets to drum, and the size of wheels is carefully designed based on mathematical calculations so puppets on the upper-level drum once every one *li* and those on the lower-level drum once every ten *li*. The project, in cooperation with a business company, developed a VR game which helps students experience sitting in the cart and listening to the drum when the cart moves along an ancient Chinese street.

After the intense buildup, a question was raised for students, “If you were in a parallel universe where the ancient Chinese methods were used to make maps, how would you draw a map of the campus?”

3.5.2 Digitalization and An Elderly-Friendly City

Embedded in a context where China’s population is aging rapidly while the number of births is falling, this project is meant to initiate a discussion with students on elderly-friendly cities. It first shared ideas of the Internet of Things (IoT) (as shown by Fig. 4), which means “things,” or “physical objects,” are connecting and exchanging data with other “things” over the internet through digital hardware and software, and then specified possibilities that IoT would make a city’s structures and services more accessible to older people with varying needs and capacities (As shown by Fig. 5).

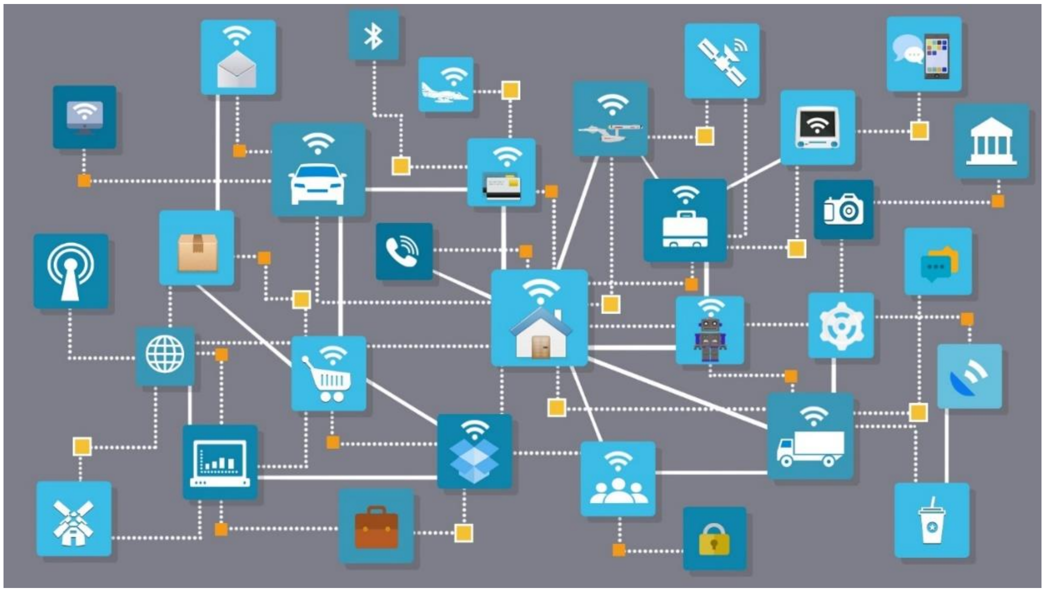

Figure 4. Illustration of IoT (Courtesy of Shao, the curriculum developer of the project)

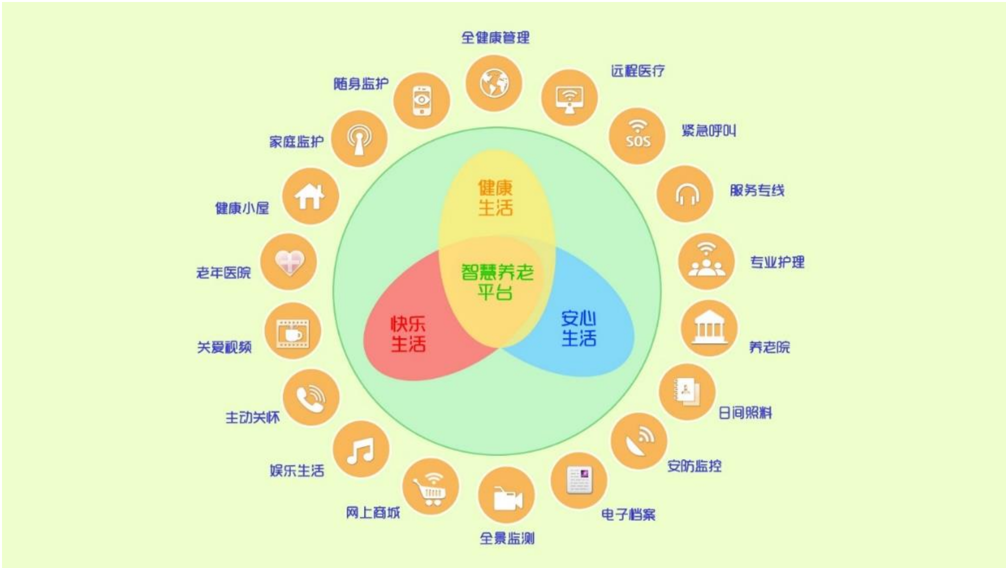

Figure 5. IoT for An Elderly-Friendly City: Possibilities (Courtesy of Shao, the curriculum developer of the project)

Figure 5 demonstrates how IoT could revolutionize the elderly care: It empowers the intelligent platform by integrating the once separate sectors such as "home monitoring," "mobile monitoring," "distance medicine," "SOS," "day care," "electronic-data archiving," "emotionally focused therapy," "online shopping mall," "entertainment," so on and so forth, in terms of data-sharing and device connection, so that senior people could live a healthy, happy, and carefree life.

Starting from the potential of IoT to actively engage all dimensions of city life in enhancing quality of life as people age, this project asked students to work in groups on this question, "If you traveled in time to 2050 and found yourself landed in a super-aged society, how would you design the structures and services of your city to accommodate the demographic shift?"

3.5.3 A City and Ocean Symbiosis

Different from the other two projects, this one started with a tough question, "If you were in a parallel universe where all human cities were submerged in sea, how would you design your city in a way that you and your fellow citizens were to survive?" Such a question is difficult to answer and students, with the support of the teacher, discussed scientific uncertainties and technical difficulties in achieving that goal. Upon their recognition that an organism, like a human, lives only as part of a complex network of all kinds of actors, the teacher introduced the concept of ecosystem. The teacher asked students to rethink the relationship between a human city and the ocean, when the explosion of the world population and the expansion of the human city were disrupting the oceanic ecosystem, and humans, like other components of the ecosystem, were suffering the consequences. Students finished three tasks: First, they explained the concept of "ecosystem" with a real-life example; Second, they surveyed and found what was going on in human-ocean interactions (polar ice caps melting, sea level rise, coastal erosion, marine litter, and wetlands" disappearance); And third, they brainstormed ways of making a city and ocean closer to symbiotic, e.g., wetlands restoration and a marine litter recycling plan.

3.5.4 Analysis

STEM educators in the U.S. will benefit from this project since it deconstructs Man, the coordinates of modern education, without falling into the hands of the God-like algorithms. First, the fact that PEI Xiu's principles of mapmaking, which resonates with those of the "modern" cartography, dates to the third century contests the "western origin" of "science" and disentangles "science" from a "rational" subject; Second, reviving the memory of collecting and presenting cartographic information, especially as a traveler delivering personal narratives, reacts against geographic information systems (GIS) as *the* way of mapping. GIS adopts digital technology and manages huge data sets to "overlay" positions on Earth's surface with geographical data such as past environmental conditions of a particular location, allowing visualization of current spatial patterns and trends (like the traffic) and predictions of future scenarios. Born with the unique problems of digitalization, i.e., the politics of creating, storing, checking, and displaying data, and heavily relying on perceptions through remote sensing (the satellite's panoptic view), GIS risks conceding the rights to interpret spatiality and make one's positionality totally based on databases and algorithms. Hence, it is necessary to always keep an eye on societal and ethical implications and to figure out possible alternatives conceptually and practically for mapmaking—that is what the project has done. Third, rather than constructing a "Chinese" man against Man's violence, this project makes subject by constantly othering perception. Every time the teacher set the stage of parallel universes or time travel, he was taking away the problems and the "toolkit" for problem-solving that students were familiar with: Elderly health issues do not usually manifest themselves during adolescence, and the deadly threats of marine litter that the ocean wildlife is facing everyday are hardly experienced by the majority of humans living in a "human" community. In Deleuze's tripartite complex of subjectivation "subject-space-time," reframing space and time means disrupting the stabilized construct of subject, so the project's imaginaries of a past, a future, and a distant place opened up the subject "here and now" to the otherwise imperceptible spaces and times, and enriched its repertoires of formulating/solving life problems and existing with Others. Othering perceptions constantly would not lead to the construction of an essentialized subject, be it Man or a "Chinese" man, but keeps subject an ongoing process of becoming *Others*: Becoming traveler-cartographer, becoming the aged, and becoming animal/plant/ocean. It is in this way that STEM education helps students become not only acquainted with STEM skills but also aware of the implications of STEM trends, especially those leading to Self-Other tensions.

The final assignment of the project is to let each group of students design and make a model of the future city according to their understanding and imagination. The following photos (fig. 6 & 7) show two of the works students presented:

Figure 6. A Model of the Future City: A Contraction of Time and Space

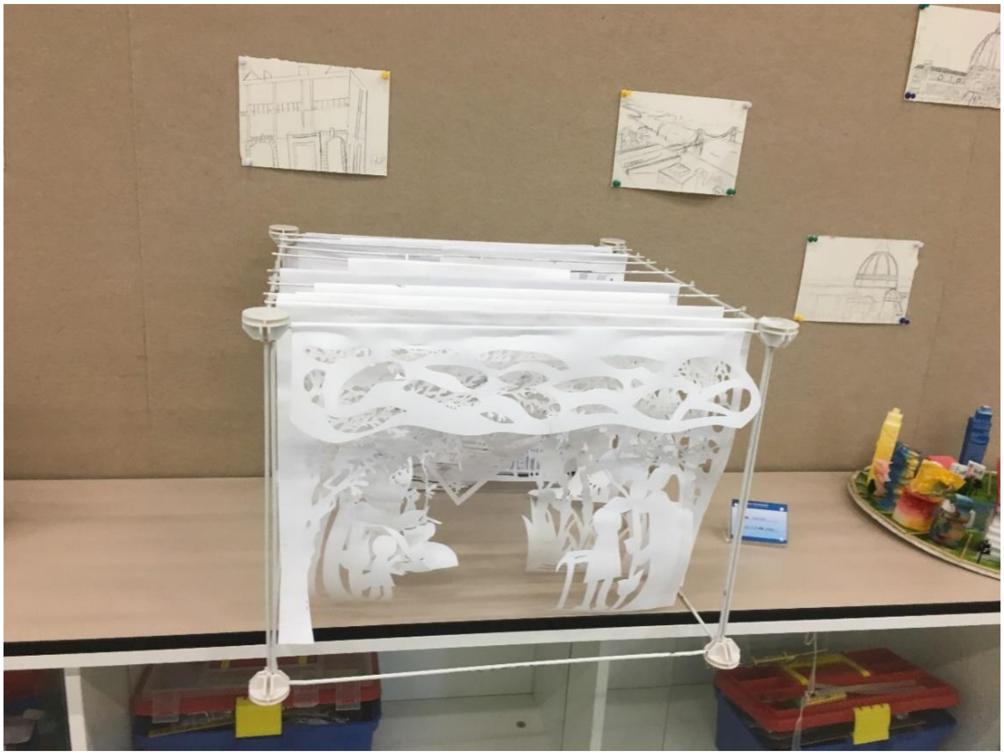

Figure 7. A Model of the Future City: A Layered Ecosystem

Th work presented in figure 6 illustrates a nonlinear temporality and an overlapping spatiality: Different epitomes of the city Hangzhou are placed together in a non-chronical order (see the year on their tags: Unidentifiable date, 379 AD, 2018 AD, 404 AD…) to conceptualize the "future city" as a contraction of times and spaces. The work in figure 7 uses papercutting to demonstrate the complexity and fragility of the "future city": Images of the elder (who leans on her walking stick), the child, the plant, the animal, and so on, layer upon one another, indicating the mutual dependence of multiple actors which constitute the urban ecosystem.

In sum, this project defamiliarizes students' experience of their own present to help them adjust their positionality and their relations with Others. It encourages students to fully appreciate the diversity of *being* and *knowing* through the teaching and learning of STEM, especially in a context when the grand narrative of Man, of algorithms, or of a "Chinese" man tends to make some groups less heard and seen. Its integration of ontology, epistemology, and ethics, as also manifested in Daguan middle school's motto, "Honoring What Makes You Possible and Meeting Practical Ends from There" [*敦本务实*], attends to the "dystopia" that marks the U.S. STEM education discourse, the *"-isms*" that obsess the U.S. STEM educators, and, more generally, worries and sufferings caused by the impotence in defining what a "human" is in a digital era and how to cope with tensions between "human" and its Other, as exemplified by the abandonment of the elders in a Spanish nursing house during the Pandemic and by the concerns about the AI-human competition/hostility (see the beginning of chapter 2 for both examples).

3.6 CONCLUSION

Chapter 3 discussed how trends in digitalization condition STEM education in the U.S. in terms of contents, pedagogies, and goals, and how STEM education in the U.S. neglects the paradigm shift of the subject through digitalization. Chapter 3 proposed “othering perception” to address the problem of subjectivation in U.S. STEM education and translated a STEM project in China with Deleuze’s “subject-space” language in the hope that U.S. educators could resonate with such an example of “othering perception” to meet challenges posed by the local and global context.

Chapter 4, which is also the last one, summarizes what has been done throughout the work, as well as what collectively the writing opens for the field of educational research. It also talks about the limitations of the work and the weakness of Deleuze’s theory of subjectivation. At last, it points out new directions to future research.

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4. Education on the Shaky Ground of Humanism:

From Digitalization to Postdigitalization

> Ask yourself about the basics, about water, air, and fire. Remember the game 20 Questions? You begin by giving a hint as to whether you are thinking of an animal, a vegetable, or a mineral. OK. I am thinking of none of them. I am thinking of 100111100010110001.
>
> NICHOLAS NEGROPONTE, *Beyond Digital*

4.1 INTRODUCTION

At the end of the 20th century, Negroponte (1998) carefully portrayed a future world "beyond digital," where "being digital will be noticed only by its absence, not its presence" and, despite the banality of "digital," "the really surprising changes … in our lifestyle and how we collectively manage ourselves in the world" will always remain unpredictable: "We know that the higher we climb, the thinner the air, but we haven't experienced it – we're not even at digital base camp" (n. p.). Cramer (2015) substitutes Negroponte's term "beyond" with the prefix "post" and explicates that,

> the prefix "post" should … be understood … in the sense of post-punk (a continuation of punk culture in ways that are somehow still punk, yet also beyond punk); post-communism (as the ongoing social-political reality in former Eastern Bloc countries); post-feminism (as a critically revised continuation of feminism,

> with blurry boundaries with “traditional,” unprefixed feminism) … and, to a lesser extent, post-apocalyptic (a world in which the apocalypse is not over, but has progressed from a discrete breaking point to an ongoing condition…) (p. 14)

In other words, to put “beyond” and “post” before “digital” is to verbalize digits, the “100111100010110001,” regarding them as “an ongoing condition” under which historical constructs get repeated and differentiated to create and/or satisfy immediate needs.

Overall, this work attempts to understand the changing landscape of “modern” education in general and U.S. STEM education in particular by examining the reconfiguration and continuation of historical constructs “subject” and “space” as posed by digitalization. It sees digits as “an ongoing condition” rather than stabilized numeral structures, therefore having looked into the “beyond” or “post” digital state of education/STEM education. Though a contextualized understanding of such a state is necessary, this work recognizes a general trend that the “strange figure of knowledge” (Foucault, 1989, p. xxv), Man, is being deconstructed and complicated, as “knowledge has discovered a new form” through digitalization: Knowledge is produced as streams of bits, reproduced at nearly zero marginal cost, and transmitted in no time all over the world. Education is on a shaky ground of humanism.

Chapter 4 elaborates some broader implications for education on the shaky ground of humanism. In the first section, it explicates the significance of this dissertation as a move “beyond” or “post” digital. Second, it will summarize key findings from individual chapters in relation to the research questions. Next, it will expound on this work’s contributions to different fields of education. Fourth, it will discuss limitations in terms of a regional focus and the weakness of Deleuze’s theory of subjectivation. And finally, it will propose directions for future research.

4.2 SIGNIFICANCE: FROM DIGITALIZATION TO POSTDIGITALIZATION

Jandirć et al. (2018) urge educators to explore the "postdigital" state as it "does describe human relations to technologies that we experience, individually and collectively, in the moment here and now" (p. 896). To exemplify how "post" indicates "a 'holding-to-account' of the digital that seeks to look beyond the promises of instrumental efficiencies" (p. 895), they reviewed some of the emerging trends in "science, education, arts, and various other areas of human interest" as part of "the ongoing social-political reality" in digitalized societies. Such trends designate shifts occurring ontologically, epistemologically, and ethically. For example, ontological shifts include Donna Haraway's cyberfeminism (1985/1991, as cited in Jandirć et al., 2018, p. 893), Katherine Hayles' "deconstruction of the liberal humanist subject" (Pötzsch & Hayles, 2014, as cited in Jandirć et al., 2018, p. 893), and William Gibson's cyberpunk roots of the "posthuman" (Gibson, 1984, Jandirć et al., 2018, p. 893). Epistemological shifts include digital ways of creating and disseminating knowledge (Peters et al., as cited in Jandirć et al., 2018, p. 895), online education (Knox, 2016, as cited in Jandirć et al., 2018, p. 895), and networked learning (Jones, Ryberg, & de Laat, 2015, as cited in Jandirć et al., 2018, p. 893). And ethical shifts include the Silicon Valley solutionism (Morozov, 2013, as cited in Jandirć et al., 2018, p. 895), the reproduction of algorithms' predetermined prejudices (O'Neil, 2016, as cited in Jandirć et al., 2018, p. 895), and the fabrication of 'truth' out of the abundant information flows (Peters, et al., 2018, as cited in Jandirć et al., 2018, p. 895).

"Messy; unpredictable; digital and analog; technological and non-technological; biological and informational," the postdigital state is "a reconfiguration in our existing theories and their continuation" and its messiness "seems to be inherent to the contemporary human condition." In this sense, this work is an attempt to investigate the postdigital state, the "reconfiguration" in existing theories of subject and space as well as their continuation, of "modern" education and a specific setting, namely, U.S. STEM education. This work conjoined Foucault's genealogy of the subject with Wynter's descriptive statements about Man to rethink the attribution of digitalization to the messiness "inherent to the contemporary human condition" in "modern" education. It also attended to the advent of philosophical assumptions embedded in one outgrowth of digitalization, U.S. STEM education, and then examined a specific STEM project at a Chinese middle school to trace mutations in the figure of Man enacted in a specific site. The analysis demonstrated the advent of new possibilities of subjectivation by mobilizing the Deleuzian complex of "subject-space."

4.3 SUMMARY OF KEY FINDINGS

Chapter one was composed of an extended discussion of several topics. First, issues and problems regarding digitalization raised in 'modern' education, such as the "digital divide" and "digital use divide," the prejudice built in the digital black box, and the marketization featured with the grass-roots users' voluntary contribution and self-responsibilization. Secondly, based on Foucault's historiography of the subject and Wynter's analytics of Man, the issues and problems related to increasing digitalization were posited as forging a reconfiguration in existing theories of the subject and space that underlie "modern" education. Here, the work demonstrated how the subject and space operated as sliding signifiers within a western philosophical canon, elaborating Wynter's notions of Man 1 and Man 2 and the shifting conceptualization of space from ancient Greek to contemporary quantum physics ideas (Pythagoras, Plato, Aristotle, Democritus, Newton, Leibniz, Kant, and Einstein). Third, the dissertation articulated the manner in which Deleuze's theory of subjectivation offered one possibility for reconceptualizing how digitalization impacts and redefines notions of the subject and space. Chapter one thus responded to Research Question 1 and 2, i.e., "What issues and problems in regard to digitalization have been raised in the contemporary discipline and practices of education?" and "Drawing on Foucault's historiography and Wynter's analytics of Man, how can issues and problems in regard to digitalization be understood in relation to conceptions of the 'subject' and 'space' that found 'modern' education?"

Chapter two investigated a particular set of philosophical traditions: Descartes' science as the "clear light of reason" and Kant's science as the "intuition *a priori*." These philosophies help to make possible "modern" science and STEM (science, technology, engineering, and mathematics) education. Chapter two also mobilized Foucault's analytical tool "statement" to explicate the discursive formation of STEM education in the U.S., which highlights Man as a rational subject, Man's space as a container, and Man's time as a one-directional linearity. Drawing on Wynter's descriptive statements about Man as political and socio-economical, chapter two detailed the unfulfilled promises of U.S. STEM education to improve "human' conditions, as demonstrated by the prevalence of various "-isms." Chapter two also suggested that STEM education should be approached by checking the politics of "human" conditions first. Chapter two provided a contextualized reply to Research Question 2, and partly answered Research Question 3, i.e., "How do particular philosophical traditions, discourses, and trends in digitalization enable the formation and practice of STEM education in the U.S.?" which was further discussed in chapter three.

Chapter three illuminated the co-dependence of digitalization and science/STEM, showing how digitalization helped reshape the content, pedagogy, and goal of STEM education in the U.S. Then this chapter showed what "othering" perception means through an example of cultivating "deep empathy" for "human" medical workers when they compete with AI for jobs.

It then translated the Deleuzian theory of “subject-space” into a method of “othering” perception which helped produce subjects more receptive of “inputs” and more capable of “outputs” than algorithms might predict/prescribe. Built on this understanding of “othering” perception, chapter three looked into a STEM project called “The Future City” at a middle school in Hangzhou, China. The project invoked students’ imagining of time travel and parallel universes and disturbed students’ good common sense. From the Deleuzian “subject-space” perspective, this project disrupted the established canon of subject-making and space-imaging by constantly “othering” students’ perceptions: Students perceived the world as if they were a pre-digital cartographer, an elderly person, and an ocean animal. In this way, they learned to renegotiate their positionality and Self-Other relations for here and now. Having a conversation with this project, U.S. STEM educators could open up to a wider array of histories and knowledge to facilitate students in contesting the existing “human” conditions as dictated by Man and/or algorithms. Chapter three also responded to Research Question 4, i.e., “How can Deleuze’s theory of ‘subject-space’ help address the persisting and emerging problems in the digitalization of education, in particular in a STEM-focused high school in Hangzhou?”

In the sections below, chapter 4 builds on the findings from chapters one, two, and three to develop the contributions and limitations of this work, as well as to make suggestions for future research. This last chapter will answer Research Question 5, i.e., “What are some broader implications for situating the discipline and practice of education within the processes of digitalization?”

4.4 CONTRIBUTIONS

The main contributions of this work to different subfields of education include extending prior research on topics like the “subject,” “space” and “digitalization,” increasing the conceptual vocabulary of educational technology, providing insights into a futurist scenario of knowledge production, and enriching the inventory of case studies of software. The following text will enumerate them one by one.

First, this work reverses the relationship between education and digitalization by recognizing education as now housed within digitalization rather than the other way around. It demonstrates how cybernetics is the continuation and culmination of the onto-epistemological movement that grounds modern human sciences and humanist subject, Man. Cybernetics, on the one hand, acknowledges chance or contingency as indispensable to the self-organization of animals and machines, while on the other hand, manages to design and control such self-organizing systems through statistics and probability theory. Education relies on the postulates of cybernetics, such as self-organizing, quantification, and purposiveness, to understand and engineer "humans," and, as digitalization is a recent realization of cybernetic thinking, education is not "all of a sudden" thrown into the weave of digitalization but has long been "hard-wired" as ready for digits. As such, the fatal problems of cybernetics get built into education: the reductionist coding and programming of life, the exclusion of any "noises" believed to be irrelevant to the preset goals, and the Black boxed reproduction of historical biases, or in Wynter's (2015) terms, of the sociogenic replicator codes generated by Man. This work draws on Deleuze's theory of "subject-space" to disrupt the looping production of Man and its ontological divisions. Recognizing the co-emergence of subject and space, this work, through its example of "The Future City" STEM class, illustrates how the socio-culturally sensitive curriculum and careful use of digital technologies, for example, VR, can help create unexpected imageries of space and opportunities for the students to meet Others—an otherwise silenced narrative of "science," the elderly, and the ocean and oceanic ecosystem—so that subjectification is no longer constrained to "Western" humanisms, Silicon

Valley solutionism, and "Chinese" nationalisms that permeate dominant STEM conversations. Here Deleuze's theory of "subject-space" is a methodology through which the students experienced the constant reformation of Self (the "becoming-man") by drawing on their particular cultural heritages and defying the historically salient construction of "truth" and "knowledge."

Second, this work contributes to the field of educational philosophy by extending prior research on the topic of the "subject," "space," and "digitalization." Rojo (2019) worries that the digital media's invasion of the individual's private space is threatening the construction of "an autonomous, responsible subject, the basis for education in the West" (Rödl, as cited in Rojo, 2019, p. 57). This work started from the same position that Rojo holds, i.e., the deconstruction of the humanist subject, Man, through digitalization, but moved forward along a different route by proposing to construct a de-centered subject rather than to restore the sovereignty of Man. Also, responding to Sheail's (2015) appeal that educators should be "more alert to the kind of education space [they] are importing into software environments" (p. 43), this work delineated how orientations to the "subject" were related to a history of "space" and its contextualization within the project of digitalization in/of education. Moreover, this research developed the theoretical rationale for existing linkages of "subject-space" set forth by Knox (2016). Knox suggests that the Massive Open Online Course (MOOC) presumes "uncritical and problematic forms of humanism," i.e., "the expectation of rational and self-directing individuals, with a universal desire for education," and it is such a "fundamental orthodoxy" that "limits both the understanding of technology and the possibilities for a concept of 'openness' in education" (p. 305). He sees space and time as critical sites where technological changes occur and ask for more attention to the mutual formation of the subject, space, and time. Though he mentions Deleuze-Guattari's "becoming" as an alternative framework for "thinking about the intermingling of humans and technologies in education," he does not specify the co-constitution of the subject, space, and time within such a framework. This work digs into the Deleuzian theory of subjectivation to offer educators a fuller philosophical construct that they could mobilize as both a theory and a methodology to scrutinize the change to the human condition that the digitalization of education has produced and incited.

Third, this work contributes to the field broadly defined as curriculum studies, which revolves around the politics of knowledge and wisdom, the assumptions of the non-neutrality of curricula in different settings, and the tracing of differential impacts. Curriculum studies have historically been divorced from work in educational technology, digital media, and software development, although this separation has changed in the last ten years (Juneau, 2013; Edwards, 2015; Sheail, 2015; Leahy, etc., 2019; Mertala, 2019). Edwards (2015), for example, discusses how software serves as part of the hidden curriculum of education by "selecting and shaping the information, forms of knowledge and modes of interaction available to teachers and students" (p. 265) through the work of code, algorithm, and standards. He calls for more engagement with "the active role of software in the enactments of curriculum" (p. 277). This work adds to the inventory of case studies of software by examining the digital platform edX, which provides college-level online courses and harvests users' data to improve teaching and learning, as well as Washington DC's public-school evaluation and performance management system, IMPACT, which modifies teachers' teaching and assessing behavior and their interpretation of knowledge. This work also offers insights into the futurist scenario of curriculum by sketching out possibilities for justifying education and reconceptualizing knowledge in the face of the 'technological unemployment'. Weaving together the concern about the destination of education for "a 'workless' or 'workerless' society" (Peters, 2018, p. 553) and the valorization of 'deep empathy' and close human-to-human relations in the face of human-computer competition for jobs (Topol, 2019), it is intended as an opening into the reconfiguration of politics of knowledge in a postdigital state.

Fourth, this work contributes to the field of educational technology (EdTech) by enriching the repertoire of concepts and theories that EdTech draws upon. EdTech has always been an interdisciplinary field, but with a limited set of disciplines, mostly computer science, education, and psychology. To be specific, "education" here mainly refers to cognitive learning theories, like Vygotsky's constructivist theories which sees the learner as a constructor of knowledge and learning as a collaborative process (Spector, 2001; Juneau, 2013; Dillenbourg, 2016). This work has integrated a deeper philosophical engagement into EdTech. By developing the philosophical construct of "subject-space," this research offers sites of communication and collaboration, and new questions, for professionals from different fields, e.g., "What is meant by the 'learner'?" "What is meant by the educational 'space' as the digital blurs with the physical?" and "How does one rethink the 'learner' in relation to 'space'?".

Fifth, this work contributes to the field of STEM education. It fills a gap in the existing literature about the historiography of STEM education in relation to digitalization by examining this gap in the context of "the U.S." And, different from studies *for* STEM education, which attempt to "better" STEM education and incorporate digitalization into STEM education, this work is a study *of* STEM education, examining how particular philosophical traditions, discourses, and trends in digitalization work together as conditions of possibility for "STEM education". By relating the unfulfilled promise of STEM education to improve "human" conditions to the formative process of STEM education, this writing provides new perspectives on STEM pedagogies. Also, this work participated in the ongoing discussions about globalization and travelling discourses, illuminating the delicacy of resistance against a 'global future', which presumes "modernist" assumptions of progress and autonomous subjects within a rationally ordered society (Popkewitz & Lindblad, 2004; Popkewitz, Olsson, & Pettersson, 2006; Chang, 2019). At different locations (the national education policy of China and the STEM project at the Daguan Middle School), such delicacy of resistance amid other continuities are analyzed not as mutually exclusive but as co-constitutive, as part of the ongoing refiguration of the "modern" in modern education. In this way, this work pushed forward considerations of ethical responsibilities when educational discourses attempt to transgress non-crossable borders (Baker, 2015).

4.5 LIMITATIONS: A EUROPE-U.S. FOCUS AND A THEORY OF PERPETUAL MOTION

As a study on the "messy, unpredictable" state "beyond" digital, this work makes sense only when it contextualizes the reconfiguration in existing theories and their continuation. Considering that the European colonization and U.S. domination have fundamentally shaped the present world, this work first narrows its focus to narratives of "subject" and "space" in European-American traditions (chapter 1). And considering that the assessment of skills and knowledge in science, mathematics, and reading is held as 'the world's most comprehensive and reliable indicator of students' capabilities' (Gurría, as cited in Schleicher, 2019, p. 2), it concentrates further on STEM education in the U.S. as an example of digitalization's now buried and taken-for-granted reach (chapter 2 and 3). Even though this dissertation translates a Chinese STEM project for an American-based audience in education, it is still a study based in Europe and the U.S., in terms of the histories it mobilizes (histories of Man, of space, of philosophies of science, etc.), the problems it addresses (the unfulfilled promises of "modern" education and STEM education in the U.S.), and the way the Chinese STEM project is discussed (through a

Deleuzian perspective). This understanding challenges notions of pure regionality somehow speaking for itself (Chakrabarty, 2000). With such a narrow focus, this dissertation is less capable of turning its attention to contexts beyond Europe and the U.S. to reveal the dynamics of the ongoing processes of digitalization in relation to the change of the "subject" and "space" there.

A second major limitation of this work is that it draws upon Deleuze's theory of subjectivation to address problems and issues regarding digitalization in relation to the conceptions of the "subject" and "space." This dissertation recognizes the weakness of this theory in its failure to deconstruct the dualism of motion and stillness. Deleuze as a philosopher is nourished with particular philosophical traditions, as indicated by the names of some of his major works: *Nietzsche and philosophy, Spinoza: Practical philosophy, Foucault, Bergsonism, Kant's critical philosophy*, and so on. Debates over dualism, the use of two mutually irreducible principles to account for knowing (for instance, subject and object) or being (body and mind), are integral to those traditions, so it comes as no surprise that Deleuze takes the unpacking of dualism as his lifelong enterprise. In his theory of subjectivation, subject arises as a transcending, reductive effect of pure movement (the movement of movements), and space occurs as an aggregate of the multiplicity of movements. In other words, subject occurs as movements start to form a habitual route of perception and action, through which the complete openness, full prehension, and intimate connections inherent in pure movement are tactically schematized to facilitate concerted actions. The concreteness of the world, which is called "object," is formed upon the formation of the subject, and it is not movements that take place in a receptacle called "space" but "space" that deposits itself in and through movements. Treating subject and object as different aspects of the same transcending, reductive effect of pure movement, Deleuze dismantles the long-held dualism of subject and object, and of mind and body. This deconstruction is not accomplished without a cost, as his entire line of reasoning is built on the dominance of motion over stillness. The result is that any account of stillness has to fit into the very model of perpetual motion and there stays the presumption that perpetual motion is a given and somehow important.

The dichotomy of motion and stillness and the preponderance of motion should by no means be held as universal, as Baker (2001) has already delineated via the unique conceptualizations of the "child" as shaped to theories of perpetual motion and power from Platonic Greece to the 1900s within the "Western" diffusion. Such a cultural boundedness operates as a provincialism, limiting the potentiality of Deleuze's "subject-space" complex, both as a theory and a method, to address problems of subject-making along with digitalization. The next section makes suggestions for future studies, which address the above-described limitations of the current project.

4.6 SUGGESTIONS FOR FUTURE STUDIES

First, future studies might want to address problems posed by digitalization regarding the contemporary condition of the "human" in different educational settings. Education will benefit from attending more to nuanced narratives about local politics in digitalization, especially to those about people whose stories have not always been told or "sincerely" told. For instance, the Program for International Student Assessment (PISA) by the Organization for Economic Cooperation and Development (OECD) tests "the knowledge and skills of students directly, through a metric that was internationally agreed upon" (Schleicher, 2019, p. 3) and is among the most influential educational assessments at present that countries and economies draw upon to fine-tune their education policies. The latest PISA test in 2018, with a special focus on "reading in a digital environment" (p. 4), is interpreted by the OECD official report as proposing "getting ready for the digital world" for *all*: "People who cannot navigate through the digital landscape can no longer participate fully in our social, economic and cultural life" (p. 13). However, the data of PISA 2018 comes from a pool of "600,000 students representing about 32 million 15-year-olds in the schools of the 79 participating countries and economies" (OECD, 2019, p. 19). Here, the problem is not about inclusion and exclusion; it is about normalizing how to gauge students' qualifications to be postdigital citizens in drastically different contexts, and about "representing": "600,000 students representing about 32 million 15-year-olds" and "the 79 participating countries and economies" representing human societies in general. As Cox (2015) comments, "the reconfigurations produced [by the postdigital] are neither absolute nor synchronous, but instead operate as asynchronous processes, occurring at different speeds and over different periods and are culturally diverse in each affected context" (p. 151). It is therefore necessary to investigate "the reconfigurations produced [by the postdigital]" as "culturally diverse," "asynchronous processes," if education really wants to help solve real-world problems.

Second, it is worthwhile to step out of the comfort zone of "Western" philosophies and look at other historical heritages for possibilities of rethinking the structural problems in the "West." For instance, Chinese Chan Buddhism (*Chan zong*, 禪宗) offers a radical approach to dissipating the dualism of motion and stillness. Chinese Chan Buddhism was developed in China in the sixth century as an indigenous form of Buddhism and then spread to other parts of East Asia—for instance, to Japan, where it evolved into Zen. Though "Chan" (禪) is the transliteration of the Sanskrit *dhyāna* or "meditation," it is not the meditative techniques that makes Chan Buddhism unique within Chinese Buddhism. Rather, Chan Buddhism is featured with its advocacy of the embodied realization of Buddhist awakening: The real Chan must be experienced. There is no specific way to experience Chan and realize awakening, though; one may enter enlightenment from any direction as long as he or she follows “the central doctrine” of “nonthought.” *The Platform Sutra [of Chan Master Huineng (638-713)]* explains: “‘Non’ means to be without the characteristic of duality, to be without the mind of the enervating defilements. ‘Thought’ is to think of the fundamental nature of suchness” (2000, p. 44). The state of “nonthought” is a state where one is no longer confined by any dualistic notion and has no attachment or discrimination, and therefore no “enervating defilements.” For instance, Master Sheng Yen in his book *Liberated in stillness and motion* (2017) proposes that we understand motion and stillness beyond the active and passive scheme, which in “Western” analytical philosophies posits such dichotomies instead as a proper method for perceiving and thinking. Through a non-discriminatory perceptual process, things are mirrored as they *are* at the moment of perception, so perpetual motion presents “the transcendental state of being unmoving and empty” (p. 21). Meanwhile, since “all mental activities (volitions) are impermanent” and since “all physiological, physical, natural, and social phenomena as well as mental phenomena, lack an unchanging, permanent self” (pp. 20-21), the freedom of action arises from the complete assimilation of the mind into the object-body as well as the body into the subject-mind—namely, the embodiment of the transcendental stillness into constant change. By practicing such “motion in stillness” and “stillness in motion,” one is liberated in stillness and motion and is “not attached to the world but engaged in it” (p. 23).

In short, this work proposes to make future research more contextualized in order to discern and present the delicacy of local politics, and more open in order to enrich the conceptual repertoire the research could draw on. These avenues will help the education community to resist the dominance of the master narrative.

4.7 CONCLUSION

This dissertation is a winding journey on which genuine curiosities, new scenarios, wild thoughts, and memories unfold themselves and intertwine with each other. It starts from the awkward position where "modern" education adheres to the making of Man although other ways of subjectivation through digitalization are gaining predominance. Delineating violence and suffering in relation to Man and a container-like space, where every actor competes for room for survival, and those travails in relation to the built-in prejudice and reductionism of digits, this work mobilizes Deleuze's theory of "subject-space," which offers a practical method (othering perception) of subject-making, to resist the authority of Man and algorithm.

However, the conclusion is not the ending since what is "beyond" or "post-" digital is messy and unpredictable. In Negroponte's words, we have a "blindness." The only thing we can do, then, is to keep a prudent watch, be humble, and always "take hold of certain knowledge" in the face of "an epochal change" (Blanchot, as citied in Stiegler, 1998, p. 1). Stiegler reminds us,

> Do you admit to this certainty: that we are at a turning point? — I f it is a certainty, then it is not a turning point. The fact of being part of the moment in which an epochal change (if there is one) comes about also takes hold of the certain knowledge that would wish to determine this change, making certainty as inappropriate as uncertainty. We are never less able to circumvent ourselves than at such a moment: the discreet force of the turning point is first and foremost that.

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