Education Systems and Technology in 1990, 2020, and Beyond

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Abstract

In *Restructuring Education Through Technology*, I incorporated systems thinking to identify seven types of relationships in educational systems: teacher-student, student-content, student-context, teacher-content, teacher-context, content-context, and education system-environment relationships (Frick 1991). I now revisit these education system relations and discuss potential futures of education. The World Wide Web did not exist when I wrote the original treatise, nor did wireless smartphones and tablets, Google's search engine, YouTube, Facebook, or Wikipedia. However, one important education system relationship should not change: the affective bonding between teachers and their students.

Keywords education system · computer technology · systems thinking · educology · system component relationships · adaptive instruction · future education systems

Introduction

As we enter the 2020 decade, 30 years have passed since I wrote a small book in 1990 called *Restructuring Education Through Technology* (Frick 1991). It was published about the same time as the World Wide Web first became available to the public, in August, 1991 (https://en.wikipedia.org/wiki/World_Wide_Web).

In the present article, I discuss important differences and similarities in education systems and technology in 1990 and 2020. I provide examples of education system affect-relations and system properties, then and now. I conclude with a strong philosophical stance on what is most important in the future.

What Is a System?

Ludwig von Bertalanffy (1950a, 1950b, 1972) was a biologist who is well-known for his initial development of *general system theory* (GST). GST was intended as an organizational framework or paradigm applicable to many scientific fields, what von Bertalanffy originally considered a unifying science. Many

others built upon von Bertalanffy's foundational work, including Maccia and Maccia (1966), Wymore (1967), Mesarović (1972), Comacchio (1972), Weinberg (1975), Berlinsky (1976), Lin (1999), and Ackoff and Emery (2017). Thompson (2006a, 2006b) briefly discussed the history of GST through the twentieth century, including the significant contribution of the SIGGS Theory Model (Maccia and Maccia, 1966). Predicate calculus was used to logically define approximately 80 terms. Thompson (2019) further refined these and other terms in *Axiomatic Theories of Intentional Systems* (ATIS).

Underlying these efforts is the fundamental goal of logical precision in use of terminology which describes *general system*, *education*, and *education system*. For example, *system/negasystem* flows were identified such as *feedin*, *feedout*, *feedback*, and *feedthrough*, and *system* structural properties were denoted such as *size*, *complexity*, *strongness*, *flexibleness*, *wholeness*, and *hierarchical order*. Further temporal properties included *system openness*, *spillage*, *filtration*, *regulation*, *adaptiveness*, *compatibleness*, and *stress*.

I present here a fundamental translation and description in natural language to support the main focus here. Think of this introduction to basic systems properties here as a guided tour of a building with many rooms. Readers can go as deep and detailed as they wish by following links to the web to explore further.

Figure 1 depicts an overview of fundamental systems concepts. The Appendix contains an abridged glossary of terms, which I have translated to natural language definitions.

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Fig. 1 Basic schema for system and negasystem

The first distinction is between a *system* and its *negasystem*. A system is defined as “a set of components and a family of *affect-relations*” (Thompson 2019; <https://aptac.sitehost.iu.edu/glossary/atisSystem.pdf>). The *negasystem* is, literally, the not-system. In natural language, many people refer to *system environment*, but a distinction is made between *toput* and *negasystem* in SIGGS and ATIS. *Toput* is the *system environment*, which is part of the *negasystem*. *Toput* is what is available for selection by a *system*. If a system is *open*, then some of *toput* may later become *system input*. That temporal process is *feedin*. Some *toput* may not become *input*, what is termed *system spillage*. *System filtration* is a restriction of *feedin*.

Parallel terms include *system fromput* and *system output*. The process of stuff exiting the system is *feedout*. See Fig. 1 and the Appendix. *System feedin* and *feedout* are temporal processes. At time 1, some components are part of *system toput*, and at time 2 they are part of *system input*. *System feedback* is *feedout* followed at a later time by *system feedin*.

There are also *structural affect-relations*, which refer to the configuration of connectedness among component *affect-relations*, which are relatively stable over some period of time. *Temporal affect-relations* refer to the changing temporal configurations of event occurrences. In Fig. 1, *system affect-relations* are represented by the shape with arrows. In ATIS and SIGGS, mathematical digraphs (directed graphs) are used to characterize *affect-relations*. In order to keep matters relatively simple here, I will not digress into digraph theory, although it should be noted that it is fundamental to network analysis and complex systems, for example (e.g., see Jensen and Nielsen 2007; Brandes and Erlebach 2005). Noteworthy also is that components and their *affect-relations* also occur in the *negasystem*. Finally, due to space restrictions, more than

80 other important *systems* properties and their definitions are not discussed here. A broader description is available in Frick (2019) and on the Educology Website (2020) at: <https://educology.iu.edu>. Further details are provided in the ATIS glossary at <https://aptac.sitehost.iu.edu/glossary/> and Thompson (2019).

What Is an Education System?

An *education system* is but one kind of system. There are many kinds of systems, including systems of government, military, biology, economy, health care, etc., to name just a few. Some systems are *intentional*, while others are not (Thompson 2019). An *education system* is an *intentional system*. *Intention* refers to willing, i.e., trying to do, seeking a goal. The primary goal of an education system should be to guide student learning (Steiner 1981, 1988).

An *education system* is defined as an “*intentional system* that consists of at least one *teacher* and at least one *student* in a *context*” (Educology, 2020: <https://educology.iu.edu/educationSystem.html>).

Note the differences between Figs. 1 and 2. Now we are referring to an *education system* and an *education negasystem*. Note further the *affect-relation* shape in the education system, which now indicates relations among *teachers*, *students*, *content*, and *contexts*. Note also *education system toput*, which is the *education system environment*, which includes persons and things available for selection by an *education system*. Examples of *affect-relations* in *education systems* and *negasystems* are provided in Tables 1, 2, 3, 4, 5 and 6 below.

Finally, and most important, an *education system* is not confined to a place such as a school building with classrooms.

Fig. 2 Basic schema for an education system and education negasystem

This expansion is extremely important, and in fact is one of the main differences between 1990 and 2020 education systems. Some current *education systems* span the whole planet, and *education system feedin* and *feedout* occur through a network of networks referred to as the Internet and Worldwide Web.

An *education system* requires:

- One or more *teachers* to guide student learning;
- One or more *students* who intend to learn;
- Guidance of learning that occurs in a *context* (i.e., a setting which also includes *content* for learning) (<https://educology.iu.edu/educationSystem.html>)

Note this conception of an *education system* consists of *universals*, not limited to time or place (<https://educology.iu.edu/universals.html>). Thus, *education systems* are not limited to schools or universities as we now know them.

- *Teachers* need not be limited to licensed school teachers or college professors.
- *Students* need not be restricted to young people attending a school or university.
- *Contexts* for teaching and learning need not be classrooms in school buildings or on college campuses.

Table 1 Teacher-student relationships

Same: 1990 and 2020	Different: 2020
Teachers continue to directly guide student learning face-to-face in classrooms in school and campus buildings; and via field trips with students outside of schools.	<p>Teachers directly guide student learning in their classes remotely and in real-time through online connections in ways that include synchronous chat and two-way video (e.g., Google Hangouts, FaceTime, Skype, Zoom).</p> <p>Teachers guide student learning in their classes by making recorded videos played back via the Internet (e.g., using course management systems such as Canvas, Blackboard, and Moodle); by making screencasts (e.g., voice over PowerPoint slides); by sending e-mail and text messages; by creating course websites; by contributing to online discussion forums; etc. Some of these can be very large online classes, referred to as MOOCs.</p> <p>Students on the job can continue their education; working professionals can also moonlight as teachers in these programs—who may not have teaching licenses or advanced degrees but who are competent practitioners.</p> <p>Online education programs also can facilitate a much greater diversity of students from different countries, cultures and ethnicities for teachers to guide. These programs further provide students with opportunities to learn from a far greater diversity of teachers.</p>

Table 2 Student-content relationships

Same: 1990 and 2020	Different: 2020
We still have content in textbooks, magazines, newspapers, recorded movies, videos and music, etc. for students to use as resources for learning.	<p>Students live in an environment and culture that now includes vast resources available through the Internet. This is the new “library” accessible via smartphones, tablets, and computers.</p> <p><i>Augmented reality:</i> with portable devices it’s possible to provide content overlays as students visit real-world contexts.</p> <p><i>Web search results:</i> Google search is possibly the best example of artificial intelligence (AI) thus far. Type in a few words, and we can often get a list of Web links to highly relevant documents.</p> <p><i>Siri, Alexa, Cortana, Google Assistant, Dragon Naturally Speaking, and other agents with voice recognition:</i> These are yet another way to browse the Web via AI voice recognition techniques.</p> <p><i>Virtual reality, virtual worlds, simulations, video games, and animated movies:</i> We continue to push the frontiers of what technology can do.</p> <p><i>Fingerprinting, face recognition, and other ways to identify unique individuals:</i> This is important not only for filtering access to digital devices for security reasons, but also can be used for adapting content and contexts for teachers and students.</p> <p><i>Student creation of content:</i> This is relatively easy now using current technologies. Not only can students write papers using their laptop computers or Chromebooks, they can also create video stories with smartphones or digital cameras, edit them, and post their work online.</p>

Table 3 Teacher-content relationships

Same: 1990 and 2020	Different: 2020
Teachers can access content in the same ways as do students, described in Table 2.	Teachers can access content in the same ways as do students, described in Table 2.
Teacher professional development activities often occurred when students were not in school, and to seek an advanced degree often meant taking a leave of absence during the school year or taking in-person courses on a college campus during summers, nights, and weekends.	<p>Teachers can continue their own learning via online programs during the school year without taking a leave of absence from their jobs. They can also pursue advanced degrees online.</p> <p><i>Better content creation tools:</i> shooting and editing still images and videos; creating slide shows for presentation; making websites; developing computer tutorials and tests/quizzes, simulations, and games.</p> <p><i>Content management systems</i> such as Canvas, Blackboard, and Moodle facilitate teacher collection of learning resources for their students, posting their course syllabi, for making assignments and providing feedback on student work, managing discussion groups, using online gradebooks, and facilitating other class activities.</p>

Table 4 Student-context relationships

Same: 1990 and 2020	Different: 2020
Students continue to physically attend formal classes in school buildings and on college campuses.	Students can individually use portable digital devices (e.g., iPads, Chromebooks, laptop computers, smartphones) that run on batteries and connect wirelessly to local and remote networks, not only in school classrooms, but also for doing homework outside of school.
Younger students who have not reached adulthood still need direct supervision by adults in environments that are safe.	Adult students of all ages now can take formal classes online, where they can earn diplomas, degrees, and certificates from home or from just about anywhere with Internet access.
	Students can interact with their peers, friends, and others through social media—including Facebook, Instagram, Snapchat, Twitter, etc.
	There are many ongoing distractions in the environment that can disrupt student attention to learning activities. Instead of noisy peers in a school classroom, students at other times and places are frequently interrupted by notifications from their devices—e.g., new text messages, e-mails, likes or dislikes of their social media posts, news alerts, etc.

- *Content* need not be limited to traditional subjects of study in schools or universities such as mathematics, history, language arts, music, chemistry, biology, physics, etc.

(1991). Note that these are primarily examples of *structural affect-relations* in *education systems* and *negasystems*.

These ideas are illustrated in Tables 1, 2, 3, 4, 5 and 6, when comparing what was the same in 1990 and 2020, and what is new and different. The list is not exhaustive but is illustrative and parallels largely the organization in Frick

Discussion

When I first drafted this article in late 2019, novel coronavirus was largely constrained to China. While I finalize the current

Table 5 Teacher-context relationships

Same: 1990 and 2020	Different: 2020
Teachers used blackboards, marker boards, and overhead projectors for classroom group presentations.	These have been supplemented or replaced by teacher use of digital projection devices (LCD/LED projectors) and large display devices (such as flat-screen TVs) for classroom group presentations.
Teachers would occasionally invite others from outside school to participate in classroom activities.	Teachers can now virtually bring in guest teachers to their classrooms via video conferencing.
Teachers would occasionally make special arrangements to take their students on field trips.	Teachers can take their students on virtual field trips, while remaining physically in school classrooms.
Teachers spend most of their time in school buildings and classrooms when working with students. In 1990, they were largely disconnected (no phones, computers, wi-fi, or Internet) in the classroom.	Many teachers can connect digitally to the “outside” world while in their school classrooms (i.e., to the Internet via wi-fi, smartphones, tablets, and laptop or desktop computers).
	Teachers can work from home and still interact with students over the Internet (e.g., Zoom, Hangouts, Facebook) and via course management systems (e.g., Canvas, Blackboard, Moodle).
	Perhaps the greatest context change is that teachers can now teach from just about anywhere to adult students also located just about anywhere—if both have online access. Teachers are freed from the constraints of needing to be in a classroom with students physically present at the same time.

Table 6 Content-context relationships

Same: 1990 and 2020	Different: 2020
Content is stored in printed books, recorded videos, movies, on bulletin board displays, etc. which are physically located in school buildings and classrooms.	<i>Digital content storage:</i> digital information can be stored in a variety of devices, either local or remote. On computer devices themselves we have had hard drives, solid-state drives (SSDs), DVD/CDs, thumb drives, SD cards, and the like. These are non-volatile storage, and so retain the digitally encoded information without an active power source. More and more now, storage is available on remote devices accessible through the Internet (i.e., the Cloud).
Content is further stored and distributed via mass media such as cable TV, newspapers, magazines, movie theaters, etc.	<i>Wikipedia:</i> Remote storage also makes feasible collaboration among users with Internet access and permission to make changes in content. Wikipedia and other shared hypermedia systems employ a community approach to content development.
Physical libraries and museums function to curate and store content.	<i>Lack of access:</i> People who live in rural areas or in poverty, including the homeless, are significantly disadvantaged with respect to opportunities to use many of these digital technologies for accessing content.

article in June, 2020, a worldwide pandemic has been declared by the World Health Organization. In the U.S. many K-12 schools and colleges and universities have shut down their physical facilities (school buildings and campuses), and students and teachers were told to stay home during the past several months. Most teachers and professors have been suddenly thrown into a new context to do “emergency remote teaching” as a quick adaptation with little preparation (Hodges et al. 2020).

Nonetheless, while the physical facilities have been shut down, most *education systems* have not. The biggest structural change has been the *education system context*: students and teachers have remained physically located in their respective homes, and most student-teacher affect-relations have occurred via the Internet—at least for those who have access to the technologies required (e.g., through Zoom, e-mail, and course management systems, but see especially Table 6, last item in the right hand column). Those unfortunate have-nots have become disconnected from the education systems to which they belonged prior to the coronavirus pandemic (see ATIS property: <https://aptac.sitehost.iu.edu/glossary/atisDisconnectedComponentsSet.pdf>.)

The other obvious structural change since 1990 in *student-context* and *teacher-context* affect-relations is the current prevalence of digital devices and wireless connectivity to the Internet (wi-fi and cellular), as well as in *content-context affect-relations* (NCES 2018). Increasing amounts of *content* are now digitally encoded and stored in the Cloud (i.e., data centers accessible through the Internet: https://en.wikipedia.org/wiki/Cloud_computing).

One of the biggest challenges in 2020 is *education system filtration* (i.e., restriction of *feedin*). In 1990, publishers of

textbooks, videos, and movies for education served as significant *filters*. What was available in *education system environments* (toput) was restricted through highly centralized control within the publishing industry and mass media outlets (see Thompson 2019, <https://aptac.sitehost.iu.edu/glossary/atisCentralness.pdf>).

In 2020, the *size* of content components (sheer numbers) in the *education system environment* (toput) is larger than that in 1990 by many orders of magnitude. There are so many more choices in 2020 of what is available in the *education system environment* when compared with 1990, especially on the Internet (e.g., see Bonk 2009; Mitra 2020; Waks 2016). For example, there were no websites in 1990, one in 1991, and now there are over 1.5 billion in June, 2020 (<https://www.internetlivestats.com/total-number-of-websites/>). YouTube reports that there are over 2 billion logged-in users each month, who watch over one billion hours of video *daily* (<https://www.youtube.com/about/press/>). The website developed at Indiana University on *How to Recognize Plagiarism* was viewed over 66 million times between 2016 and 2019, with nearly 600,000 students from 222 countries who had passed a certification test (<https://plagiarism.iu.edu/recentChanges.html>). The role of teachers in “selecting the best of culture” is still relevant, and now even more so with so much content available to students worldwide (Frick 1991, 2019).

Control of potential *content* for *education systems* has become much more decentralized in general, except in countries such as China where their government has barred access to “inappropriate” content by their citizens and students and teachers in Chinese education systems. The Chinese

government has implemented a significant *filter*, restricting *education system feedin* (Xu et al. 2011).

On the other hand, in the U.S. and other countries which support more *system openness*, lack of effective *filters* has become a significant concern for educators, especially in K-12 schools (Bengfort 2019). Most of the vast resources on the Internet are unfiltered and uncured—so there is a quality issue—it can often be difficult to determine what is trustworthy, safe, or accurate. For example, there are “fake news” publications, pornographic websites, and many other unsuitable materials (Kakutani 2018). Many K-12 school systems have attempted to *filter topup*, i.e., restrict Internet access at school by their students and teachers, by limiting which websites or Internet domains they can access (CIPA 2000).

Furthermore, students in 2020 can interact with their peers, friends, and others through social media—including Facebook, Instagram, Snapchat, Twitter, etc. Unfortunately, sexual predators and bullies also have access to these apps. Parents of students may try to put *filters* on their home networks, in order to restrict access to websites they consider to be inappropriate. But clever students can circumvent such attempts, especially when outside their home networks (e.g., see Hoffman 2019).

Space prevents further elaboration of important systems concepts in understanding similarities and differences in education systems in 1990 and 2020. However, I hope that the usefulness of universal systems concepts is patent to *TechTrends* readers.

What if? What Could be?

I now want to address future education systems. Artificial intelligence (AI) and robot teachers could be in future education systems. We already have some examples of AI, such as Alexa and Siri. Just verbally ask a question, and in seconds there is an answer or a list of likely resources.

As mentioned earlier in Table 2, the Google search engine is likely the best current example of AI. Google bots roam the Web constantly, indexing billions of web pages. The Google Page Rank methodology effectively captures human judgment of what is important and relevant by examining what web page developers include as content and hyperlinks to other websites (e.g., see <https://en.wikipedia.org/wiki/PageRank>). Proprietary algorithms subsequently developed at Google have gone far beyond the original page rank method created by Brin and Page (1998) when doctoral students at Stanford University.

This raises the question that I posed over 20 years ago: “Will these globally interconnected, multimedia computer-television-telephone-stereo-radio systems largely replace teachers? Will these multimedia tutoring systems be intelligent enough to do so?” (Frick 1997, p. 108). First, there is a distinction between *adaptive instruction* vs. *intelligent*

tutoring systems. We can already do adaptive instruction with today’s technologies. On the other hand, sentient machines as possible teachers is a futuristic scenario—one that is not within our reach with current technologies.

Adaptive instruction means essentially that what a student encounters next is customized or tailored according to what she or he has done in the past (e.g., Johnson and Sloan 2020). Historically, this was referred to as *programmed instruction*—i.e., structured by an instructional flowchart with decision nodes for branching (Heinich et al. 2002). In *education systems* terms, this is computer-mediated learning software that is designed to guide student learning (i.e., is instructed learning), and which has temporal properties of *adaptiveness*, *feedback* and *feedthrough* in order to increase *compatibleness* with student learners, and which has structural properties of *flexibleness* and *wholeness*. This we can do with present technologies.

Though we might not realize it, this kind of adaptiveness and customization has been going on as we surf the Web through techniques of storing browser cookies and *digital fingerprinting* (for an overview, see <https://www.nytimes.com/2019/07/03/technology/personaltech/fingerprinting-track-devices-what-to-do.html>). If you ever wondered how those running shoes you were shopping for on *Amazon.com* show up as an advertisement in *Rolling Stone Magazine*, here is what is going on in the “black box” you are using: When you visit some websites, they plant “tracking devices” on your computer, typically stored as *cookies* by your web browser (e.g., Chrome, Firefox, Safari, or Edge) and in more recent years by using your *digital fingerprint* and matching it against those recorded previously by websites.

In addition to cookies, our devices leave digital fingerprints that can uniquely and accurately identify us individually (Eckersley 2010). These device fingerprint and cookie data are in turn used by businesses for customizing advertisements tailored to match our unique profiles (Chen 2019). These kinds of data can also be used for more clandestine purposes—e.g., as tools for influencing democratic election outcomes, that is, how we vote—by determining which political messages to which we are individually more receptive, what Pariser (2011) calls a “filter bubble” (e.g., see Baer 2016).

In adaptive instruction, as we humans interact with computer software (now called “apps”), these programs can store records of what we have been doing while using the app. These records can in turn be used in conditional logic to govern what is displayed next by the computing device. Highly sophisticated pattern recognition can provide information that drives the conditional logic. This kind of adaptation *can* be done in computer tutorials, games, simulations, drill and practice, tests, etc. as part of an *education system*. Over the past five decades, I myself have engineered software programs that are adaptive, and have taught graduate students to do likewise (e.g., Enfield et al. 2012; Frick 1989; Frick, et al., 2020; Welch and Frick, 1993).

This kind of adaptation has long been done by human teachers as they become uniquely acquainted with their students and provide instruction that is appropriate for those students' specific interests and ability to learn. Computer software today can emulate this kind of adaptation up to a point, the primary limitation being the "sensory apparatus" of the computing device (Frick 1997). Think of this kind of adaptation as a "smart" e-learning textbook, which is different for each student, depending on what she or he does and has learned thus far.

Next, I discuss so-called *intelligent tutoring systems* which are currently beyond our reach. Science fiction writers have envisioned some futuristic scenarios.

For example, Arthur C. Clarke (1968) included HAL as a central character in *2001: A Space Odyssey*. The astronauts on the outer space mission conversed in natural language with HAL, played chess games, and queried HAL about ship operations, who was central to running the spaceship. In *The Moon is a Harsh Mistress*, Robert Heinlein (1966) described Mycroft Holmes (Mike), which was a sentient supercomputer who conversed with humans in natural language, could program itself, and was smart enough to help rebels living on the moon to overthrow the Lunar Authority, an arm of government controlled from planet earth. Mike and HAL were stationary computers.

In *The Robots of Dawn* (Azimov 1983), Daneel and Giskard were robots who moved around. Central to the plot, they helped a human detective solve a murder case—the death of another robot. Daneel was embodied in humanoid form, nearly indistinguishable from actual humans in form and function, including sex. And while Daneel was incredibly intelligent, Giskard, who was not humanoid, turned out to be even more sentient. This and other science fiction novels by Isaac Azimov were famous for introducing the "three laws of robotics"—prime directives for robots to follow: not harming human beings, following their orders, and self-preservation (https://en.wikipedia.org/wiki/Laws_of_robotics). In *3001: The Final Odyssey* Clarke (1997) provided a further futuristic sci-fi scenario. "Braincaps" and "brainboxes" were sophisticated devices that could rapidly download knowledge to a human brain, essentially providing an instant education. Braincaps also allowed a human to have imaginary experiences—a virtual reality that was just as real as dreams, while interacting with others with their own virtual avatars.

In non-fiction, Ray Kurzweil (1999, 2005) envisions a future where humans and robots meld, transcending biology. He discusses six epochs of evolution, starting from physics and chemistry and ending with the universe waking up. He predicts that intelligence will evolve far beyond its current embodiment in organic forms, not unlike the underlying premise of Clarke's first odyssey novel, centered around the mystery of intelligent, powerful monoliths buried on Earth's moon and orbiting Jupiter.

These are but a few images of humankind's future. Could future education systems turn out in any of these ways? Will we someday have humanoid robots, braincaps, or literally a universal mind?

Over 20 years ago, I discussed some of the major issues that will need to be addressed (Frick 1997), and many of these issues remain unresolved in 2020. More recently, Anderson and Rainie (2018) surveyed 979 experts on artificial intelligence who expressed their concerns and suggested solutions for our future. Notably, Erik Brynjolfsson, one of the experts surveyed, emphasized that, "... the right question is not 'What will happen?' but 'What will we choose to do?' We need to work aggressively to make sure technology matches our values."

I, too, take a similar position. Rather than trying to predict what might be, I next discuss what education *should be*, taking a philosophical position.

What Should be?

Education is vital to society and our future.

Worthwhile education for everyone is the goal of making intrinsically good and instrumentally good education accessible to everyone everywhere. Every human being has a right to worthwhile education. Why? To:

- Enhance the quality of life.
- Reduce inequality.
- Minimize suffering.
- Maximize overall good.

We can do this together. How?

- Connect good teachers with students to help them learn worthwhile content.
- Provide contexts to support these connections for teaching and learning.
- Provide a viable way to sustain worthwhile education for everyone.

(<https://educology.iu.edu/worthwhileEducation.html>)

The conclusion reached by Greenspan and Benderly (1997) identifies the essence of the matter for human education:

Computers may be able to perform certain cognitive operations, even more effectively, and certainly faster, than humans. But unless they acquire the ability to experience and react to emotion, silicon chips will be unable to exercise intelligent discrimination.... What separates human intelligence from that of computers, robots, androids,

and any other cyber-creatures we can imagine, is the fact that we possess a nervous system capable of—indeed specifically designed for—generating and evaluation of affect.... Unless and until we solve the problem of creating living cellular reactivity and affects, as well as the capacity to abstract patterns of affects, in an artificial form, no machine will think in a truly human way. (pp. 126–127)

Human teachers are essential to education. It is vital that teachers and students form affective bonds. This is the most important relationship in education systems that must be nurtured, no matter how technology might evolve. This is not an empirical claim from science or praxiology. It is a philosophic claim about *what should be* (Steiner 1981, 1988, 2009).

The conclusion at the end of *Restructuring Education Through Technology* is still relevant now and in the future, as it was then:

... the technology cannot select the best of culture for sharing with students.... In short, the technology cannot evaluate the worth of the content that we embody in the medium. That is our essential role as teachers. We must select the best of culture and share it with the next generation. (Frick 1991, p. 32)

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Compliance with Ethical Standards

Conflict of Interest The author declares that he has no conflict of interest.

Research Involving Human Subjects and/or Animals No data on human subjects or animals were collected for this study.

Informed Consent No informed consent was obtained, since no human subjects were involved in this study.

Appendix

Abridged Glossary

System =_{df} “a set of components and a family of *affect-relations*” Thompson (2019).¹

Affect-Relation =_{df} a set of relations either between components or between temporal events, or both.

- *Structural Affect-Relation* =_{df} the configuration of connectedness among components.
- *Temporal Affect-Relation* =_{df} the changing temporal configuration of events.

¹ For the more precise predicate calculus definitions, see Thompson (2019, <https://aptac.sitehost.iu.edu/glossary/>). The symbol, ‘=_{df}’ means ‘equals by definition’.

Negasystem =_{df} not *system*, i.e., components and *affect-relations* not in a *system*.

System Toput =_{df} the set of components in the *negasystem* available for selection by the *system* (synonym: *system environment*).

System Input =_{df} the set of *negasystem* components selected by the *system*.

System Fromput =_{df} the set of *system* components available for selection by the *negasystem*.

System Output =_{df} the set of *system* components selected by the *negasystem*.

System Feedin =_{df} the *temporal affect-relation* for *system toput* at time 1 and *system input* at time 2.

System Feedout =_{df} the *temporal affect-relation* for *system fromput* at time 1 and *system output* at time 2.

System Filtration =_{df} restriction of *system feedin*.

Education System =_{df} an *intentional system* consisting of at least one *teacher* and one *student* in a *context*.²

Context =_{df} the setting for *teaching* and *learning* that contains *content*.

Content =_{df} *signs* of objects and objects selected for *student learning*.

Teaching =_{df} the *intentional guidance* of another person’s *learning* (synonym: *instructing*).

Learning =_{df} the increasing of *complexity* of *mental structures*.

Student =_{df} a person who intends to *learn content* with a *teacher*.

Teacher =_{df} a person whose *intention* is to *guide* another’s *learning*.

Intention =_{df} willing (i.e., trying to do, seeking a goal; synonym: *conation*).

Teacher-Student Affect-Relations =_{df} *structural* and *temporal affect-relations* among *students* and *teachers*.

Student-Content Affect-Relations =_{df} *structural* and *temporal affect-relations* among *students* and *content*.

Student-Context Affect-Relations =_{df} *structural* and *temporal affect-relations* among *students* and *context*.

Teacher-Content Affect-Relations =_{df} *structural* and *temporal affect-relations* among *teachers* and *content*.

Teacher-Context Affect-Relations =_{df} *structural* and *temporal affect-relations* among *teachers* and *context*.

Context-Content Affect-Relations =_{df} *structural* and *temporal affect-relations* between *contexts* and *content*.

² Note that an education system should not be assumed to be synonymous with a physical place, such as a particular school system—e.g., a district in a city or county consisting of school buildings containing classrooms. Components and their affect-relations can be in *different physical locations*—e.g., students could be at their different homes, teachers at their homes, and the content on YouTube (via the Internet); teachers and students could communicate through the Internet (e.g., by texting, Zoom, Facebook, etc.). For further information and examples, see the *Educology* (2020) website: <https://educology.iu.edu>

References

- Ackoff, R. L., & Emery, F. E. (2017). *On purposeful systems*. New York, NY: Routledge.
- Anderson, J., & Rainie, L. (2018). *Artificial intelligence and the future of humans*. Washington, DC: Pew Research Center Retrieved from <https://www.pewresearch.org/internet/2018/12/10/artificial-intelligence-and-the-future-of-humans/>.
- Azimov, I. (1983). *The robots of dawn*. Garden City: Doubleday.
- Baer, D. (2016, Nov. 9). *The 'filter bubble' explains why trump won and you didn't see it coming*. New York Magazine: The Cut Retrieved from <https://www.thecut.com/2016/11/how-facebook-and-the-filter-bubble-pushed-trump-to-victory.html>.
- Bengfort, J. (2019). How K-12 schools can use next-generation content filtering to keep students safe. EdTech Focus on K-12, Apr. 8. Retrieved from <https://edtechmagazine.com/k12/article/2019/04/how-k-12-schools-can-use-next-generation-content-filtering-keep-students-safe-perfon>
- Berlinski, D. (1976). *On systems analysis*. Cambridge, MA: MIT Press.
- Bonk, C. J. (2009). *The world is open: How web technology is revolutionizing education*. San Francisco, CA: Jossey-Bass.
- Brandes, U., & Erlebach (Eds.). (2005). *Network analysis: Methodological foundations*. Berlin: Springer Verlag.
- Brin, S. and Page, L. (1998). The anatomy of a large-scale hypertextual web search engine. Retrieved from <http://infolab.stanford.edu/pub/papers/google.pdf>.
- Chen, B. X. (2019, July 3). 'Fingerprinting' to track us online is on the rise. Here's what to do. New York Times, retrieved from <https://www.nytimes.com/2019/07/03/technology/personaltech/fingerprinting-track-devices-what-to-do.html>
- Children's Internet Protection Act (CIPA) (2000). U. S. federal communications commission. Retrieved from https://www.fcc.gov/sites/default/files/childrens_internet_protection_act_cipa.pdf
- Clarke, A. C. (1968). *2001: A space odyssey*. New York, NY: Signet Books.
- Clarke, A. C. (1997). *3001: The final odyssey*. New York, NY: Ballentine Books.
- Cornacchio, J. V. (1972). Topological concepts in the mathematical theory of general systems. In G. J. Klir (Ed.), *Trends in general systems theory*. New York, NY: Wiley-Interscience.
- Eckersley P. (2010). How unique is your web browser? In M. J. Atallah M.J. and N. J. hopper (Eds.), *Privacy Enhancing Technologies*. Berlin, Germany: Springer. Retrieved from <https://panopticklick.eff.org/static/browser-uniqueness.pdf>
- Educology (2020). Knowledge of education. Retrieved from <https://educology.iu.edu>
- Enfield, J., Myers, R., Lara, M., & Frick, T. (2012). Innovation diffusion: Assessment of strategies within the Diffusion Simulation Game. *Journal of Simulation and Gaming*, 43(2), 188–214.
- Frick, T. (1989). Bayesian adaptation during computer-based tests and computer-guided practice exercises. *Journal of Educational Computing Research*, 5(1), 89–114.
- Frick, T. W. (1991). Restructuring education through technology. Bloomington, IN: Phi Delta Kappa Education Foundation. Retrieved from <https://tedfrick.siteshost.iu.edu/fastback/fastback326.html>
- Frick, T. W. (1997). Artificially intelligent tutoring systems: What computers can and can't know. *Journal of Educational Computing Research*, 16(2), 107–124 Retrieved from <https://tedfrick.siteshost.iu.edu/epistemology/aitutor.pdf>.
- Frick, T. W. (2019). Importance of educology for improving education systems. In J. M. Spector, B. B. Lockee, & M. D. Childress (Eds.), *Learning, Design, and Technology: An International Compendium of Theory, Research, Practice and Policy: Systems thinking and change* (E. G. Kowch, Vol. ed.). Cham: Springer Nature Switzerland AG. https://doi.org/10.1007/978-3-319-17727-4_92-1.
- Frick, T., Dagli, C., Barrett, A., Myers, R., Kwon, K., & Tomita, K. (2020). How to recognize plagiarism: Tutorials and tests. Bloomington, IN: Department of Instructional Systems Technology, School of Education, Indiana University. Retrieved from: <https://plagiarism.iu.edu/acknowledge.html>
- Greenspan, S. I., & Benderly, B. L. (1997). *The growth of the mind and the endangered origins of intelligence*. Reading, MA: Addison-Wesley.
- Heinich, R., Molenda, M., Russell, J., & Smaldino, S. E. (2002). *Instructional media and technologies for learning* (7th ed.). Upper Saddle River, NJ: Merrill Prentice Hall.
- Heinlein, R. (1966). *The moon is a harsh mistress*. New York, NY: Tom Doherty Associates.
- Hodges, C., Moore, S., Lockee, B., Trust, T., & Bond, A. (2020, March). 27. EDUCAUSE Review: The difference between emergency remote teaching and online learning Retrieved from <https://er.educause.edu/articles/2020/3/the-difference-between-emergency-remote-teaching-and-online-learning>.
- Hoffman, C. (2019). 5 ways to bypass Internet censorship and filtering. Retrieved from <https://www.howtogeek.com/167418/5-ways-to-bypass-internet-censorship-and-filtering/>
- Jensen, F., & Nielsen, T. (2007). *Bayesian networks and decision graphs* (2nd ed.). NY: Springer.
- Johnson, C. and Sloan, A. (2020). Adaptive learning: Implementation, scaling, and lessons learned. EDUCAUSE Review. Retrieved from <https://er.educause.edu/articles/2020/4/adaptive-learning-implementation-scaling-and-lessons-learned>
- Kakutani, M. (2018). *The death of truth*. New York, NY: Tim Duggan Books.
- Kurzweil, R. (1999). *The age of spiritual machines*. New York, NY: Viking Penguin.
- Kurzweil, R. (2005). *The singularity is near: When humans transcend biology*. New York, NY: Penguin Books.
- Lin, Y. (1999). *General systems theory: A mathematical approach*. New York, NY: Kluwer Academic/Plenum.
- Maccia, E. S., and Maccia, G. S., (1966). Development of educational theory derived from three educational theory models. Project Number 5-0638, Office of Education, U.S. Department of Health, Education, and Welfare. Columbus, OH: The Ohio State University Research Foundation.
- Mesarović, M. D. (1964). Foundations for a general systems theory. In M. D. Mesarović (Ed.), *Views on general systems theory*. New York, NY: John Wiley and Sons.
- Mesarović, M. D. (1972). A mathematical theory of general systems. In G. J. Klir (Ed.), *Trends in general systems theory* (pp. 251–269). NY: John Wiley & Sons
- Mitra, S. (2020). *The school in the cloud: The emerging future of learning*. Thousand Oaks, CA: Corwin.
- National Center for Educational Statistics (2018). Computer and internet use. Retrieved from <https://nces.ed.gov/fastfacts/display.asp?id=46>
- Pariser, E. (2011). *Filter bubble: How the new personalized web is changing what we read and how we think*. London: Penguin Books.
- Steiner, E. (1981). *Educology of the free*. New York, NY: Philosophic Library.
- Steiner, E. (1988). *Methodology of theory building*. Sydney: Educology Research Associates.
- Steiner, E. (2009). Ethical theory. (lecture notes). Retrieved from <https://tedfrick.siteshost.iu.edu/steiner/Ethical%20Theory.pdf>
- Thompson, K. R. (2006a). "General system" defined for predictive technologies of A-GSBT (axiomatic-general Behavioral systems theory). *Scientific Inquiry Journal*, 7(1), 1–11.
- Thompson, K. R. (2006b). Axiomatic theories of intentional systems: Methodology of theory construction. *Scientific Inquiry Journal*, 7(1), 13–24.

- Thompson, K. R. (2019). Axiomatic theories of intentional systems (ATIS) and options-set analyses for education. In J. M. Spector, B. B. Lockee, and M. D. Childress (Eds.), *Learning, Design, and Technology: An International Compendium of Theory, Research, Practice and Policy: Systems thinking and change*. (E. G. Kowch, Vol. ed.). Cham: Springer Nature Switzerland AG.
- von Bertalanffy, L. (1950a). An outline of general system theory. *British Journal for the Philosophy of Science*, 1(2), 134–165.
- von Bertalanffy, L. (1950b). General system theory: A new approach to unity of science. *Human Biology*, 23(4), 302–312.
- von Bertalanffy, L. (1972). The history and status of general systems theory. In G. J. Klir (Ed.), *Trends in general systems theory* (pp. 21–41). London: Wiley.
- Waks, L. J. (2016). *Education 2.0: The LearningWeb revolution and the transformation of the school*. New York, NY: Routledge.
- Weinberg, G. M. (1975). *An introduction to general systems thinking*. New York, NY: John Wiley and Sons.
- Welch, R., & Frick, T. (1993). Computerized adaptive mastery tests in instructional settings. *Educational Technology, Research and Development*, 41(3), 47–62.
- Wikipedia (n.d.). The free encyclopedia. Retrieved from <https://www.wikipedia.org/>
- Wymore, A. W. (1967). *A mathematical theory of systems engineering: The elements*. NY: John Wiley & Sons
- Xu, X., Mao, Z. M., & Halderman, J. A. (2011). Internet censorship in China: Where does the filtering occur? In N. Spring & G. F. Riley (Eds.), *Passive and active measurement* (pp. 133–142). Berlin, Germany: Springer-Verlag.

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