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Teaching, Learning, and Climate Change: Anticipated Impacts and Mitigation Strategies for Educators

Donny Newsome[1] · **Kendra B. Newsome**[1] · **Scott A. Miller**[1]

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Abstract

The impacts of climate change present numerous risks to the present and future state of teaching and learning. Natural disasters such as hurricanes, heat waves, flooding, blizzards, wildfires, sea level rise, and droughts threaten our ability to produce the learning outcomes promised to our pupils. Taking action to adapt to imminent climate-related challenges and mitigating measures that provoke and prolong ecological challenges is critical to the survival of these cultural institutions. Paradoxically, centers of teaching and learning can be seen as both victims of climate change as well as an instrumental part of the solution. Providing an efficient and effective education to the world's youth is a catalyst for the innovations that future generations of skilled professionals will use to combat climate change. Educational settings are also crucial venues for raising social awareness about anthropogenic climate change to undermine the complacency and denialism that have stagnated the global response to this crisis thus far. This paper incorporates suggestions from climate scientists and learning scientists about how to change *how* we teach, *where* we teach, and *what* we teach to ensure teaching enterprises survive and thrive in the face of a changing climate.

Keywords Teaching · Learning · Education · Climate Change · Sustainability

Introduction

The effects of climate change are upon us, and the time for prevention has passed. Renowned climate scientist Dr. Lonnie Thompson describes humankind's three remaining options: "mitigation, adaptation, and suffering" (Thompson, 2010, p. 153). The extent to which we successfully mitigate and adapt in the long term remains to be seen, but some suffering is virtually assured for humans and many other species. The effects of climate change presently being observed are understood to be inalterable; thus, there is no path to the restoration of prior ecological

✉ Donny Newsome
DrDonny@FitLearners.com

[1] Fit Learning, Reno, NV, USA

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conditions (IPCC, 2022). This is a stark reality for the world's children, whose shoulders will carry a greater weight of these burdens than the generations before them. The legacy of successful climate action they inherit will be insufficient to shield them from the necessity of finding solutions to problems their forebearers failed against. However, before we condemn our youngsters to apocalyptic outcomes, there is still an opportunity to bequeath them the skills they need to adapt, mitigate, and reduce suffering.

In light of these realities, a mandate of schools will be to provide the skills and abilities needed to survive and thrive in a depleted ecosystem. For all but a scarce collection of indigenous and alternative cultural groups, new ways of thinking and living which are not presently realized must be invented and learned, or perhaps re-learned, to achieve global sustainability. In other words, education systems must do for future generations what they did not do for us. Schooling as we know it requires a wholesale transformation. In the context of global warming, schools play dual roles. On one hand, schools can be a powerful tool in the fight against climate change. On the other hand, they are also in the crosshairs of becoming another casualty of climate change. Without considerable safeguarding, the ability of institutions of learning to continue effective operation is threatened.

There is a vast literature covering engineering and material solutions to prepare schools for a changing climate. These solutions include utilizing renewable energy sources, providing students with electronics for online instruction, and hardening structures against storms, fires, floods, mold, heatwaves, and so on. Despite the advantages that re-engineering campuses may bring, disruptions to the learning environment can still be expected. Even the best engineering may be overwhelmed by the capricious forces of nature. Therefore, this manuscript intends to focus on what behavioral science can offer educators in the search for teaching strategies that are more efficient, effective, and resilient than those commonly deployed now. The recent global pandemic has laid bare the vulnerabilities of our current educational practices and will serve as a starting point for understanding the potential implications of climate-driven schooling disruptions in the future. Although our analysis is primarily based on K–12 educational data from the United States, the ubiquity of both pandemic and climate change risks bolster confidence in the generalizability of our assertions and suggestions.

Lessons from the Pandemic

The COVID-19 pandemic has provided an opportunity to witness and study the impacts of extensive disruptions to schooling and related services. Throughout the pandemic, schools have enacted various fast-changing policies to stop the spread of the virus (see Viner et al., 2020). Modified school schedules, temporary closures, extended periods of online instruction, social distancing, and mask-wearing have been commonplace disturbances to teaching and learning routines. Such efforts to mitigate the contagion were necessary to save lives and were effective in doing so (Milne et al., 2021). Unfortunately, the disarrangement of schooling as we knew it also entailed negative externalities.

Learning Impacts

For millions worldwide, severe disruptions caused by the pandemic are ongoing. As such, a complete accounting of its current and long-term impacts on student achievement may not be known for years. What is known is that school closings and transitions to remote learning paradigms impacted instructional practices and the ability to assess learning gains with fidelity. Middleton (2020) suggested that evaluations of test scores collected early in the pandemic may not be viable to determine the extent of learning impacts because (1) in some schools, standardized testing was altogether canceled, and (2) assessments of learning designed for implementation in traditional, in vivo classroom settings are not validated for use with online learning environments.

In 2020, researchers estimated student outcomes using pre-pandemic data to circumvent the absence of reliable data from schools, a necessary adjustment due to unprecedented interruptions in face-to-face learning. Kuhfeld et al. (2020) provided projections of likely learning losses based on historical observations of the effects of seasonal learning patterns (summer breaks), absenteeism, and weather-related school closures. Their projections suggested learning gains in reading to be 32% to 37% below normal and 50% to 63% below normal for mathematics in the 2019–2020 school year. Notably, the historical datasets on which these projections were based provided no ability to account for the potential traumas experienced by students during the pandemic, which are likely to magnify learning losses.

More recent interim assessment data from the 2020–2021 school year, including in-person and remote testing results, provide empirical support for the grim projections above. For example, Pier et al. (2021) evaluated the standardized testing results of ~100,000 4th to 8th-grade students enrolled across 19 local education agencies in California. By the mid-point of their 2020–2021 school year, these students already had a learning lag of 2.6 months in English language arts (ELA) and 2.5 months in mathematics.

Social Justice Impacts

Nearly 50% of low-income families and 42% of families of color could not access sufficient technology resources to participate in online instruction, and high-poverty schools reported higher rates of absenteeism during the pandemic (Kuhfeld et al., 2020). In addition, school districts were slow to provide technology to bridge the digital divide and to provide plans for students with disabilities and special needs requiring classroom accommodations (Lake & Dusseault, 2020). Unfortunately, available data appear to support that pre-existing inequities in educational attainment, household health, housing, and economic security for poor, disabled, and minority families have been exacerbated by the pandemic (El-Mohandes et al., 2020).

Mental Health Impacts

Children and adolescents had their worlds upended by COVID-19 and consequent closures. In addition to being removed from their classrooms, children missed opportunities for social events, athletics, field trips, art, music, time with extended family, etc. According to the Office of the Surgeon General (2021), more than 140,000 children in the U.S. lost a parent or grandparent in addition to suffering from COVID-19 themselves. The advisory warns that childhood symptoms of anxiety and depression have doubled since the start of the pandemic, and hospital admissions for suicide attempts are up 51% for adolescents compared to 2019.

Economic Impacts

Fernald et al. (2021) reported Census Bureau findings that nearly 86% of students in the U.S. participated in remote learning due to school closures during the pandemic. They estimated that commensurate losses in educational attainment would have lasting impacts on workforce productivity and the economy. For example, future reductions in workforce earnings are expected to peak at −0.5% in 2045 ($150 billion, inflation-adjusted), with effects lasting through 2091. Additionally, an estimated 5% parental income loss during school closure is expected to precipitate lower parent and governmental investments in education, exacerbating expected declines in the educational attainment and productivity of the future workforce (Fuchs-Schündeln et al., 2020).

More to Come

In the United States, over 50 million students and teachers spend 30 or more hours per week in schools (Sheffield et al., 2017). Climate change makes the obligation to ensure schools maintain a safe and healthy environment all the more imperative. The Intergovernmental Panel on Climate Change (IPCC, 2022) outlines dozens of foreseeable ways the worsening climate and unalterable impacts will continue to compromise our educational systems and facilities. Many of these expected negative externalities overlap with those observed during the pandemic. In this context, the COVID-19 pandemic should be seen not as a passing, once-in-a-century event but as a dress rehearsal for the near future. Put briefly, the days of school closures, online instruction, masking, and so on are not behind us.

Climate Change Risks to Schools

There is no region on the planet where the ability to educate children is insulated from the effects of climate change. Increases in rainfall, flooding, wildfires, droughts, disease, cyclonic storms, food scarcity, sea level rise, and snowstorms have been attributed to human-induced climate change (IPCC, 2022). Such events are expected to increase in frequency and intensity through at least the near term, 2021–2040 (SPM-8).

The specific risks to schools will depend mainly upon geography. Risks are generally highest along coastlines, near seasonal rivers, and in areas where people live close to their upper thermal limits. Accelerating rates of sea level rise will result in the submergence of coastal ecosystems and infrastructure. Impacts in exposed areas include disrupted water and energy services, climate migration, and violent conflicts over increasingly scarce resources (p. 13). Mountainous regions are at the highest risk for hydrological changes induced by retreating glaciers and reduced snowpack (SPM-8). Even Arctic residents face flooding risks and infrastructure damage due to melting permafrost. Climate-change-induced increases in the incidence of water-borne, food-borne, and vector-borne diseases, including zoonoses (diseases that spread between animals and humans), are expected to continue (SPM-10). Many of these consequences are unavoidable regardless of future emissions scenarios (p. 13).

Climate-change-induced school disruptions can be expected to replicate and even magnify many of the same negative impacts resulting from the COVID-19 pandemic. Humanity will face the risks of learning loss, economic loss, and scarcity of vital resources again. The pandemic has illuminated that those burdens will not be equally distributed across socio-economic classes. Economically disadvantaged and marginalized communities already face the worst impacts of climate change, and there is no reason to expect this trend to change. Although communities worldwide presently lack the technology, resources, and political will to reverse climate change directly in the short to medium term, the technologies of teaching needed to overcome expected learning losses are available and scalable now. The time to accomplish this monumental task is short. At worst, urgent action to reform how we teach, where we teach, and what we teach may allow us to offset learning losses. At best, doing so will transition education systems from being victims of climate change to becoming among the most powerful tools in the fight against it.

The Pandemic as a Catalyst for Change

Many parents worked from home alongside their children engaged in online learning at the peak of the pandemic shutdowns. This proximity made the lack of schools' preparedness more salient to parents, who observed their children struggling first-hand. At school board meetings across the U.S. and elsewhere, parents of all political leanings made their displeasure known. In reaction to the pandemic, governments worldwide have rolled out countless initiatives and mountains of funding to remediate the pandemic's negative impacts on students and teachers. In 2020 as part of the Coronavirus Aid, Relief, and Economic Security (CARES) Act, the United States Government allocated billions of dollars to the Education Stabilization Fund in response to COVID-19 (*Education Stabilization Fund*, 2021). The government appropriated these funds to help ameliorate the educational impact in K–12 schools and higher education by addressing access to technology and other factors related to the challenge of remote learning. In addition, the American Rescue Plan (ARP) provided another $122 billion to state educational agencies as part of the Elementary and Secondary School Emergency Relief (ESSER) fund to provide pandemic relief to K–12 schools (Department of Education Announces American Rescue Plan Funds for All 50 States, Puerto Rico, and the District of Columbia to Help Schools Reopen, 2021). ESSER funds provide opportunities for state educational agencies to develop strategies to meet students' social, emotional, mental health, and academic needs. This includes the adoption of evidence-based interventions to accelerate students' learning and support the capacity of educational institutions to implement these practices with fidelity (*U.S. Department of Education Launches Two Communities of Practice to Help States Address Impact of the Pandemic on Students*, 2021).

These actions reflect a new openness among policymakers and school administrators toward novel teaching methods that may not have been previously considered for adoption. Historically, it has been commonplace for schools to adopt a new curriculum every few years (*Curriculum Adoption Process Takes a Village, plus Months of Planning and Testing - Battle Ground Public Schools*, 2019; Partelow & Shapiro, 2018). However, new curriculum does not ensure the adoption of best-practice teaching methods. There has long been a gap between the available science on effective instruction and the willingness of educators to adopt those methods (Richards & Skolits, 2009). The present combination of new funding and desperation to help students catch up represents a rare opportunity for empirically supported methods of behavioral education to play a vital role in bolstering the resilience of educational systems.

Recent investigations into reading instruction have revealed that curricula and instructional approaches lacking evidence have dominated the United States' instructional practices (Hanford, 2022). The historical failure to adopt pedagogical strategies derived from behavioral science is not due to a lack of evidence of success (cf. Curriculum-Based Measurement [CBM], Deno, 1987; Personalized System of Instruction [PSI], Keller, 1968; Kulik et al., 1979; Salkind, 2013). Despite promising outcomes, ideological differences, top-down decision-making, and the lack of courses and fieldwork needed to train teachers to implement behavioral teaching technologies have all contributed to the limited adoption of effective strategies by the educational establishment (Berens, 2020; Newsome et al., 2021). However, since the COVID-19 pandemic, many school districts have sought new teaching strategies (Gangahagedara et al., 2021; Milne et al., 2021). In March 2021, a survey of 1045 teachers in the U.S. found that 71% reported adopting new teaching methods at least once since the beginning of the pandemic (Zamarro et al., 2021). During the lockdown in Sri Lanka, 92.6% of teachers from 19 schools reported switching to online teaching tools, with 64.7% depending on social media platforms (Gangahagedara et al., 2021). Education systems have not been so well primed for revolutionary change for generations.

How we Teach

The need for an overhaul in educational systems has been evident since long before the perils of climate change and pandemics. In the U.S., student outcomes have not improved in decades despite multiple reform efforts such as the No Child Left Behind

Act and the Common Core State Standards Initiative (Berens, 2020). Many other advanced nations have observed similar stagnation in the effectiveness of their teaching (OECD, 2015). While lamenting that fundamental changes to instructional methods are long overdue, there is also optimism in the notion that the lessons of the pandemic and the impendence of climate change may finally motivate the system from its state of inaction. The COVID-19 era has already induced rapid changes in the educational landscape. Although behaviorists have historically had an underwhelming impact on public education, amongst the current chaos can be found a unique moment in time when behavior science can play a role in the reshaping of schooling.

Adapting to Fewer Days of Instruction

A likely impact of climate change is a decrease in days of instruction for students. Events such as hurricanes and wildfires can not only make a community's school buildings and homes uninhabitable but may also destroy the infrastructure necessary for remote instruction options. Under these dire circumstances, extended spans of instructional time may be lost and unable to "make up." Therefore, educational systems must minimize learning losses despite the challenges posed by the catastrophic destruction of community resources. Attenuating the risk of learning loss when teachers lose access to their students calls for empirically supported instructional solutions. Said another way, if we want to prevent students from falling too far behind when times are bad, we must accomplish more learning when times are good.

Multiple examples of viable teaching models, pioneered mainly in the private sector by behavioral educators, have been subject to large-scale analyses. Some of the most widely disseminated models share several key features. For example, in the Scientist-Educator Model described by Newsome et al. (2021) and the Morningside Model of Generative Instruction (C. Binder, 1990; Binder & Watkins, 1990; Johnson et al., 2021; Johnson & Layng, 1994; Johnson & Street, 2012) Direct Instruction (DI), precision teaching (PT) and curriculum-based measurement (CBM), are combined to (1) produce an empirically sound approach to instructional design and concept learning, (2) design opportunities to build fluency in academic tool skills, and (3) include frequent behavioral assessments to evaluate student progress. This unique combination of technologies has repeatedly demonstrated improvements in the efficiency of instruction relative to public systems. Their ability to teach more in less classroom time is needed to overcome unscheduled school closures due to climate change. These models have been replicated in dozens of tutoring centers and private schools with thousands of learners for over 25 years, and their constituent technologies (DI, PT, CBM) are readily available for large-scale adoption in public schools.

Direct Instruction

Direct Instruction (DI) offers an empirically validated technology to ensure that educators teach effectively in their time with students. Project Follow Through is the preeminent example of the effectiveness of a DI approach to education. In the largest government-funded investigation of teaching approaches, DI yielded significantly better outcomes for students than any other educational model explored (Watkins, 1988). In the decades after Project Follow Through, numerous studies have corroborated the effectiveness of a DI approach to education, making this a viable technology for accelerating learning gains in less time (e.g., Carlson & Francis, 2002; Stockard, 2011, 2013).

The design principles inherent to DI include the analysis of behavior, communications, and knowledge systems (Binder & Watkins, 1990; Engelmann & Carnine, 1991). Behavioral principles inform how to motivate learners, present examples, prompt and reinforce responses, and how to correct incorrect responses. The secondary design principle informs the logical design of concept instruction – how to sequence instruction to prevent misrules, failures to generalize, and overgeneralization. The third design principle deals with the logical classification of knowledge forms and provides the foundation for designing instructional strategies repeated with similar forms of knowledge. As such, a DI approach removes the burden on teachers to identify and sequence examples for students and provides them with guidance on how to prompt when learning is not observed and reinforce when it is.

Precision Teaching

The Great Falls Precision Teaching project provides the earliest example of the impact of PT (Beck & Clement, 1991). In the Great Falls PT project, students received daily opportunities to build academic fluency in reading, math, and spelling tool skills. Students practiced isolated skills in 1-minute timings each day until they could perform the tool skills at a specific frequency. This structured practice significantly improved standardized test scores compared to the control groups. Moreover, longitudinal findings showed that 4th graders who participated in the PT model in earlier grades significantly outperformed 4th graders who did not (Beck & Clement, 1991).

It's been said that "…students learn what they are effectively taught, and that they master what they practice" (Binder & Watkins, 1989, p. 36). If we are faced with fewer days of instruction, it will become increasingly important that students master what they are taught more efficiently. Precision Teaching (PT) is a technology focused on establishing a solid foundation of tool skills through timed, repeated, reinforced practice that may help mitigate the negative impact of lost classroom time. Evans et al. (2021) defined PT as a "system for precisely defining and continuously measuring dimensional features of behavior and analyzing behavioral data on the [Standard Celeration Chart] to make timely and effective data-based decisions to accelerate behavioral repertoires" (p. 3). Precision Teaching, unlike DI, is not a specific curriculum or set of specific teaching procedures. Instead, PT is a technology for establishing fluency, or mastery, in tool skills required for academic success. Haughton (1972) found that the frequency and accuracy of a tool skill were a better predictor of the acquisition of the composite skill than accuracy alone. For example, students who could accurately read and write digits at 100 per minute were more likely to acquire and master addition and subtraction (cf. Binder, 1996; Haughton, 1972; Starlin, 1972).

Precision teachers have long used the language of pinpoints to communicate an instructional target precisely. Creating an instructional pinpoint (see Kubina et al., 2016) involves combining a movement cycle with a learning channel. A movement cycle includes an action verb and a noun identifying the object receiving the action. Learning channels are often added to pinpoints as an efficient way to communicate the targeted skill's stimulus modality and response topography. In a simple learning channel, the first term indicates the sensory modality by which the learner contacts the instructional stimuli. The second term, separated by a slash (/), indicates the observable response to be counted. For example, the learning channel *see/say* indicates that the learner contacts the instructional stimuli visually, and their spoken responses are counted. The resulting pinpoint clearly and concisely communicates (1) the behavior or action of interest, (2) what receives the action, (3) the modality of the stimulus evoking the action, and (4) the nature of the response to be counted. Following that template, a task such as *completing a worksheet of addition and subtraction problems* may be communicated in a pinpoint format as *see/write solves math facts*. In this way, pinpoints and learning channels are critical tools for precision teachers to operationalize concepts from DI curriculum into serviceably fluent skills.

Curriculum-Based Measurement

There is great value in an educator's ability to easily monitor and frequently assess whether students are learning and acquiring new knowledge directly related to classroom instruction. Unfortunately, as with the COVID-19 pandemic (Middleton, 2020), opportunities to engage in formal standardized testing stand to be interrupted as educators adapt to fewer days of instruction and increased online instruction. Many of the most commonly used standardized tests take hours to administer, require weeks of planning, and are delivered very infrequently. Their burdensome nature was not compatible with unexpected school closures and remote learning. Curriculum-based measurement (CBM) provides educators with an alternative, behaviorally informed technology for frequently assessing students' academic progress (Deno, 1985, 2003; Deno & Fuchs, 1987). This style of progress monitoring entails obtaining repeated measures of academic performance to assess and quantify improvement and to evaluate the effectiveness of classroom instruction for an individual student. CBM assessments are designed directly from grade-level curriculum and are often administered weekly or monthly throughout the school year.

CBM administration is brief (a few minutes), and each assessment provides educators with a time-series display of student progress that can inform instructional practices. In addition, the broad use of CBM has led to the national norm-referencing of tens of thousands of learners. That is, the performance of an individual student can be compared to the national percentile rank and can also be compared with the performance of peers within a classroom, school, or district. With this distal lens, progress on proximal targets (e.g., decoding multisyllabic words) can be compared with percentile rank gains on more global targets (e.g., oral reading fluency on a grade-level passage). Comparisons between proximal and distal gains allow educators to discover important functional relations between specific instructional variables and their broader impact on learning (Newsome et al., 2021).

A common feature of the behaviorally informed instructional models described above is that *how* we teach is given by *how* we measure learning. The technology of DI guides how to deliver the instruction of new concepts, while PT provides a framework for measuring fluency and functional mastery of those concepts. CBM offers a distal lens (Berens, 2020) for evaluating if those efforts translate into global progress and can help overcome the barriers to the validity and viability of formal standardized testing practices when school is disrupted. Antiquated calendar-based lesson planning and testing methods have resulted in pedagogical decisions being driven by dates instead of data. In behavioral education models, teachers are empowered with frequent, objective data about student learning, and their pedagogical decisions are guided by learning outcomes. The data collected as they teach will either validate the teacher's efforts or quickly reveal when a new method or strategy is needed to produce skill mastery. These practices fundamentally alter how the relationship between teaching and learning is conceptualized, from unilateral lecturing to reciprocal shaping among teacher and student repertoires.

Making Time to Teach about the Environment

When instruction is made more efficient, core academic goals can be met in less time. For example, Sawyer et al. (2021) implemented a literacy instruction program with PT, DI, and CBM components which produced an average normative gain of 16 percentile points in only 6 hours of instruction for students in a Title-1 elementary school. Once adopted, efficient instructional models informed by behavioral science can resolve multiple problems simultaneously. Not only will more efficient learning aid in producing the catch-up growth needed to resolve learning losses from the pandemic, but it will also allow spare instructional time to be allocated toward learning about climate change and acquiring the skills needed to consume sustainable reinforcers, as elaborated below.

Where we Teach

The failures of virtual instruction during the COVID-19 pandemic reveal a lack of preparedness for such a dramatic shift among educational institutions and students. In anticipation of a future of increased days of virtual instruction, educators can take proactive measures to prepare themselves and their students for this eventuality. Whereas being "caught by surprise" by the disruptions of the unforeseen pandemic may be forgivable, future disruptions brought on by climate change are foreknown, and we can be prepared when they arrive.

Adapting to Increased Online Instruction

When the next major school-disrupting event forces schools back to virtual instruction, the opportunity to prepare the relevant tool-skill repertoires will have passed. However, just as educators do not wait for buildings to catch fire before practicing fire drills, they also need not wait for the next wildfire or hurricane before teaching our students how to learn from their home computers. Practice opportunities for effectively responding to emergencies such as fires, tornadoes, earthquakes, and active shooters have been a ubiquitous feature of school schedules for decades. So too can practice for online instruction become a regularly scheduled preparatory exercise in schools.

Unlike a fire drill, the entire student body of a school need not practice online learning skills simultaneously. This fact is particularly convenient for schools lacking the resources to provide all students with the necessary equipment on campus. Instead, schools may organize students into groups as small as a single class or even fewer if needed. The same empirically supported instructional practices needed to improve the efficacy of in-class learning can also be relied upon for teaching online learning skills. Following the framework of the instructional models described above, frequent reinforced practice opportunities can provide students with mastery of these skills to ensure they are retained and serviceable when school closures occur. The instructional sequence may begin with DI, modeling, and practicing the tool skills in isolation. With enough practice, students will begin to demonstrate the ability to combine and chain the skills flexibly in the face of increasingly complex prompts and scenarios. Educators and students will have achieved the first step in skill mastery when students can independently navigate the demands of online learning in a full-day simulation. Full mastery is demonstrated when students demonstrate these skills after a period without practice, indicating functional skill retention.

Tool skill analysis (Johnson & Layng, 1992) is a valuable method for identifying the critical skills students need to navigate future periods of virtual instruction successfully. Tool skills are defined as the most basic elements of more complex skills. For example, the ability to write letters and words fluently may be considered one of many tool skills involved in the more complex repertoire of composing an essay. A tool skill can be isolated for targeted instruction and, once at strength, readily combined with other fluent tool skills to form novel response patterns and successfully operate novel contingency arrangements. The pedagogical strategy of focusing instruction on tool skills and regularly assessing the serviceability of those skills in more complex tasks (i.e., application) is characteristic of behavioral models of instruction (see Johnson and Layng's 1992 Model of Generative instruction; Newsome et al.'s 2021 Scientist Educator Model).

The tool skills required for successfully attending class in person might include finding one's classroom on campus, operating a combination lock to open a school locker, requesting a hall pass for a bathroom break, or engaging with classmates in choral responding, for example. The specific repertoire for participation in online learning is quite different and, therefore, necessitates an analysis of the relevant tools skills students will need to master. Given the diversity of electronic devices students may be using (personal or school-provided) and the variety of online learning platforms utilized across schools, it is not feasible to provide a comprehensive curriculum that applies to all settings. Nonetheless, we provide below a sampling of somewhat ubiquitous skills in online learning environments to serve as a starting point for educators.

> **Component Skills:** Typing, drag/drop, copy/paste, power-cycling the device, using a mouse or trackpad, muting/unmuting microphone, turning the video on/off, virtual hand raise/lower, requesting help, printing materials
> **Composite Skills:** Logging in/out of the learning platform, uploading/downloading documents & assignments, viewing grades & graded assignments, conducting internet speed tests, checking for/downloading operating system updates, viewing due dates/class calendars, using chat/messaging features, composing & sending/receiving emails.

A comprehensive curriculum to prepare for online instruction will likely involve fluency building on the above tool skills and many more, depending on the specific circumstances. Once a sufficient list of tools skills is identified, the next objective is to sequence the instructional targets beginning with the simplest or most fundamental tool skills (e.g., quickly clicking icons with a trackpad) and culminating with more complex tasks involving multiple tool skills (e.g., downloading, completing and submitting a multi-step, multimedia assignment). Once sequenced, skills for successful online learning can be operationalized as "pinpoints," where the movement cycle is combined with a learning channel to elaborate the instructional context. Curricula designed to support online learning skills may include pinpoints such as *see/click raises/lowers hand,* or *hear/click turns on/off camera*, for example.

Behaviorally informed teaching and management methods are uniquely positioned to take advantage of the controls present in virtual learning spaces. Once the technology-related skills for online learning are mastered, instructional models, including PT, DI, and CBM, can be readily transferred to the digital learning environment. The ability to effectively deliver instruction may even be improved. The technology-supported online learning environment enhances a teacher's ability to control content delivery, and is particularly amenable to PT, DI, and CBM. For example, precise timing and counting tools, student polling applications, and annotation features provide ample ways to teachers to assess student performance dynamically throughout lessons.

In today's technological age, educators and students can easily access online and app-based adaptations of the SCC, easing the integration of a PT approach into educational practice. Students can engage in timed practice of specific tool skills that make up both simple and complex academic repertoires. Widely available flashcard programs such as Quizlet™ afford a simple way to practice until optimal response frequencies are reached. Using online or app-based adaptations of the SCC, students can quickly analyze and make data-based decisions about their progress and identify when they need additional support. Teachers can access a student's data remotely and recommend interventions specific to that student and the specific skill. Increased measurement of a student's performance on skills related to a concept allows the educator to identify when more support is needed quickly.

The ability to time and count performance is critical to the delivery of fluency-based instruction and CBMs, and these features are readily available in online learning platforms. Break-out room features allow students to work in small groups, and for teachers to work individually with students to conduct fluency timings and additional assessments or bespoke interventions. A teacher's control of microphone and camera settings can also have several instructional advantages, especially when teaching targets are operationalized by learning channels. For example, when conducting lessons in the "hear/say" learning channel, all sources of stimulation and response options outside of that channel can be disabled. By maximizing these capabilities, teachers can be more confident that the performance observed was evoked only by the intended auditory stimulus and not incidentally prompted by visual cues. When needed, multi-modal responding is also readily facilitated in online learning environments where students can see, hear, speak, click, annotate, type, raise hands, select emojis, gesture, point, etc. Finally, screen-sharing functions allow teachers to present academic stimuli and engage students in the evaluation of their data, which is a hallmark of PT best practices (White, 1986).

Classroom management strategies informed by behavioral science are also readily adaptable to online learning environments. For example, remotely controlling students' microphones and video feeds can provide systematic consequences for targeted response classes. Teachers' enhanced control of the learning environment can be leveraged to maximize the salience of reinforcers delivered individually or in group contingency formats. Similarly, online learning interfaces can also help manage contingencies and reduce rates of maladaptive student behavior. For example, implementing a planned-ignoring protocol for attention-maintained disruptive behavior can be done by pressing the "mute" button. As a result, other students can be spared from interruption, and the salience of social consequences which previously maintained those behaviors can be substantially reduced or eliminated.

Had behavioral models of instruction been in place prior to the pandemic, their many advantages in efficiency, efficacy, and adaptability to online instruction may have spared teachers, students, and parents considerable suffering. In a future defined by climate change, *where* we teach will be a moving target. Shifts from in-person to online instruction may be frequent and of variable, unpredictable duration. As such, the fluid transition between learning environments will be a requirement of the next generation of teaching practices.

What we Teach

An important consideration for advancing an agenda in which educators prepare for a world of increasing turmoil is identifying the most critical skills for inclusion in curricula. Acknowledging that access to education may be increasingly scarce as world events prevent equitable dissemination, one approach is to select curriculum targets that will have the most generative and wide-ranging impacts or are foundational components of other concepts and higher-level synthesized curricula. The ubiquity of the consequences of global warming to be faced by future generations is a mandate for educators to develop and adopt curricula that equip students to create a more sustainable future.

SUBJECT	EXAMPLES
Agriculture/gardening	▸ Design and maintain a school garden and compost ▸ Interview local farmers, male and female, to learn how climate change affects them
Arts - Visual and Performing	▸ Create posters showing the impacts of climate change ▸ Analyze songs with environmental themes or messages
Biology	▸ Examine how climate change affects the spread of diseases such as malaria ▸ Measure biodiversity in the school yard or local community
Civics/Citizenship	▸ Interview local government officials about their actions to address climate change ▸ Plan a community clean-up of a local beach or park
Geography	▸ Do field trips to examine the causes and effects of urban sprawl ▸ Create maps showing areas of the world most at risk due to climate change
Health and Physical Education	▸ Show respect for the environment when hiking on trails around the school ▸ Examine the health risks associated with environmental factors such as air pollution ▸ List the environmental benefits of healthy practices such as active transportation
History	▸ Examine how societies throughout history have resolved conflicts and responded to environmental challenges ▸ Research traditional ecological knowledge and consider how it might apply to local sustainable development issues
Language and Literature	▸ Practice the communication skills needed to speak out about local and global issues ▸ Write poems and stories in response to photos or videos about climate change
Mathematics	▸ Make graphs to show changes in school energy use ▸ Calculate statistics, disaggregated by sex, on poverty and malnutrition at the local and global levels,
Science and Technology	▸ Investigate the natural and human factors that influence the climate ▸ Assess the social, environmental and economic impacts of common chemicals
Vocational and Technical Education	▸ Use workplace safety measures that protect the health of female and male workers and the environment ▸ Identify technological solutions that address social and environmental concerns ▸ Include environmental and social responsibility in the design of a product

Fig. 1 "Teach climate in every subject area" reprinted from Gibb (2016, p. 12)

Building a School Culture of Sustainability

The rapid adoption of more effective instructional practices in schools will not only stop the downward spiral of educational outcomes but will also position schools to play a potent role in our societal battle against the causes of climate change. In a United Nations Educational, Scientific and Cultural Organization (UNESCO) publication, Gibb (2016) advocated for school-wide approaches to climate change and provided an array of actions schools can take to "participate in the transition to more sustainable lifestyles, green economies, and sustainable, climate-resilient societies" (p. 2). Gibb's school-wide approach incorporates climate awareness throughout school governance, facilities/operation, community partnerships, teaching, and learning to support an overall school culture of sustainability. Readers are guided step-by-step through a checklist of activities organized into three phases: Plan, Take Action, Reflect and Review.

The *Plan* phase begins with a self-assessment of a school's current climate actions and impacts, informing goal setting and prioritization and providing a baseline against which success can be measured. The school develops an action plan from the self-assessment to identify specific tasks, results, and timelines. The specific roles and responsibilities of faculty, administrators, custodians, community partners, and especially students are also clearly delineated in the planning process.[1]

In the second phase, *Take Action*, the plan is brought to life, and the assignees carry out their various tasks throughout the school. Active collection of quantitative and qualitative data is essential to the execution of this phase. Suggested dependent variables include energy audits, biodiversity counts, transportation surveys, community attitude surveys, attendance records, electrical bills, teacher observations, campus photographs, student work samples, and more. Sourcing data from diverse sources is recommended to capture the wide-ranging impacts of school-wide action plans fully.

The third phase, *Reflection and Review,* is an opportunity to evaluate the overall plan and its constituent components. The school uses data collected during the implementation of the *Take Action* phase to evaluate the effectiveness of the action plan. Using data, schools may adjust ongoing projects, develop new initiatives, and discard ineffective practices. Communication is heavily emphasized during this phase to facilitate learning, accountability, and motivation. Gibb (2016) recommends publicly celebrating the school's accomplishments to sustain the momentum of successful projects.

Teach Climate Change in all Subject Areas

Gibb's (2016) paper provides a list of suggested "areas for action," identifying specific projects to be taken up throughout all aspects of a school's operations and culture. For example, one suggested area for action is "teach climate change in all subject areas." The current prevailing practice in schools is to relegate lessons about climate change, if taught at all, to particular science courses. This practice does not align with the severity of the pervasiveness of climate change impacts in the world outside of science class. Constraining the topic of climate change to the context of a particular class or subject area risks leaving students without a sufficiently generative repertoire for navigating the economic, social, cultural, ethical, technological, and political impacts of living unsustainably. Figure 1, reprinted from Gibb (2016, p. 12), provides examples of assignments that imbed lessons about climate change across all subject areas. A curriculum designed in this fashion more accurately reflects the present and future of today's students for whom the changing climate is an omnipresent factor.

[1] A detailed template for school sustainability planning can be found here: http://www.edu.gov.mb.ca/k12/esd/pdfs/sustainable_guide.pdf

Critical Thinking about Climate Change

An audience segmentation analysis conducted by the George Mason University Center for Climate Change Action identifies six distinguishable groupings among American citizens regarding their positions on climate change (Roser-Renouf et al., 2009). The six groups spanning the spectrum of concern and engagement are labeled: “Alarmed” (18%), “Concerned” (33%), “Cautious” (19%), “Disengaged” (12%), “Doubtful” (11%), and “Dismissive” (7%). This *Six Americas* study suggests that one’s beliefs about the existence of climate change and its causes can dramatically influence their engagement with climate-relevant actions. As expected, those most alarmed by climate change will likely engage in sustainability efforts. Conversely, those most dismissive of climate change are not only far less likely to support sustainability efforts but also most likely to engage in actions to actively undermine climate change mitigation efforts in their communities. The highest levels of engagement are found at opposing ends of this spectrum.

Among the many demographic and historical variables analyzed that distinguish these six groups, a notable variable is their educational attainment and information-seeking behavior. The reported educational attainment across the six groups aligns with their likelihood of engagement with climate change, whether for or against it. The Alarmed and the Dismissive groups report the highest educational attainment. The two center groups, the Cautious and the Disengaged, amount to nearly one-third of the U.S. population and report the lowest educational attainment. Being more educated is correlated with higher engagement with the issue of climate change, and being less educated appears highly predictive of inaction.

In surveying the beliefs of the low-educated, Cautious and Disengaged, Roser-Renouf et al. (2009) found that many in these groups reported that they would benefit from more information to solidify their positions, indicating the potential for plasticity in their views. Moving this large swathe of the population toward engagement with sustainability will require not only providing them with basic academic skills to consume information but also the critical thinking skills needed to parse valid information from misleading sources or intentional disinformation. Evidence for this assertion lies in what the six population segments report as their primary sources of information about climate change. The Alarmed acquire most of their knowledge on the issue via print media from scientists and environmental organizations, whereas the Dismissive are most likely to trust friends and family or conservative commentators for their information. The Dismissive are notable for their above-average preference for media sources that strongly align with their pre-existing political stance and distrust of scientists relative to other groups. The ability to insulate one’s belief systems from well-known biases prevailing in the human condition is precisely the sort of skill that curricula for critical thinking can provide to the populace, as noted by Gibb (2016).

Critical thinking is a verbal repertoire wherein an individual can evaluate the quality of an argument, consider all relevant sides of an issue, be persuaded by disconfirming evidence, make inferences from available information, and evaluate the quality of supporting evidence (Willingham, 2008). This skill is a fundamentally important aspect of comprehensive education. Thinking critically empowers individuals to evaluate the quality of information they encounter independently, protects them from rhetorical misinformation campaigns, and applies to all aspects of life regardless of education level.

A critical thinking curriculum teaches learners to weigh the relative viability of information independently as they encounter large amounts of content in daily discourse. Extracting the most significant parts of the information will allow them to make meaningful, effective, and pragmatic decisions about contemporary issues. For instance, students educated in skeptical evaluations will ask questions that unveil the relative veracity of claims made by corporations or agencies of governing bodies. In a sense, this is a problem-solving strategy analogous to the scientific method: making observations, forming ideas about those observations, developing ways to test their ideas, and evaluating the outcome of that process.

Research indicates that many students do not demonstrate critical thinking skills by the time they have finished high school or the equivalent (Willingham, 2008). Many children in the U.S. only complete primary education, 4–8% do not complete primary education (Fry, 2014), and 8% do not attend school (*New Methodology Shows That 258 Million Children, Adolescents and Youth Are out of School*, 2019). Further, college attendance has declined by more than 9% since 2010 (Hanson, 2022). Alternatively, students pursuing higher education in college or graduate school are significantly more likely to develop critical thinking skills (Huber & Kuncel, 2016). Projecting out these observations, we can calculate that only 42.1% of consumers and the electorate are likely to have had any education in critical thinking and analysis by attending college in the United States (Hanson, 2022). These numbers cannot account for those raised in households where critical thinking is valued, nor those individuals who are conditioned against logical argumentation by anti-intellectual rhetoric such that they do not obtain critical thinking skills even when exposed. More research is needed to evaluate strategies to implement and evaluate critical thinking curricula earlier in students' academic experiences. Such an effort may increase the likelihood that these future leaders will be informed participants in the effort toward climate action, and the vanguards who will defend the education (and thus, climate actions) of subsequent generations.

Skilled Consumption

The most significant categorical barrier to sustainability is generally understood as the "overconsumption" of natural resources. Grant (2010) provides both support and nuance to this idea in his analysis of consumption behaviors, which he organizes into "skilled" and "unskilled" types. The importance of this distinction lies in the fact that not all consumption is equally resource intensive. For example, luxury fur coats and T-bone steaks are far more resource-intensive commodities than singing or playing board games with friends. This distinction brings needed specificity to the problems of consumption: we over-consume resource-intensive commodities and under-consume resource-light commodities.

Moving the public from resource-heavy to resource-light consumption habits is more complicated than just asking for it, educating people about it, or making resource-light commodities more available. This is because many resource-light commodities require *skilled consumption,* whereas many resource-heavy activities require little to no skill. For example, environmentally friendlier activities such as reading books or playing the harmonica require literacy and music skills. In contrast, resource-intensive practices such as yachting or riding on a private jet require little to no consumption skills. Those lacking sufficient skills to consume resource-light commodities should not be reasonably expected to abstain from economic participation. Nor should we expect people to "self-correct" their lack of consumption skills. Even if they could, contingencies may not support doing so as the difficulty of learning new skills stands in stark juxtaposition with the immediacy of reinforcement from unskilled consumption habits. Instead, it falls on our educational systems to ensure that the skilled consumption repertoires for all citizens are the product of our school's efforts.

At present, our educational system is primarily focused on workforce preparation. As such, being "more educated" by this system may produce a more skilled laborer, but, by the state of our degraded environment, we have no evidence to assume it will produce a more skilled consumer. The linkages between wealth, educational attainment, and resource consumption are clear and discouraging. While there is a vast gap in educational attainment between the rich and the poor (Filmer & Pritchett, 1999; Pfeffer, 2018), the rich are responsible for far more negative environmental externalities. According to Gore (2020), 52% of global carbon emissions were attributed to the wealthiest 10% of the population, whereas the poorest 50% were responsible for only 7% of carbon emissions during the same period. To summarize, more wealth may beget more education, but more education and/or wealth does not beget more skilled consumption. That more education does not result in better environmental stewardship exposes a systematic failure in teaching skilled consumption.

Grant (2010) rejects prevailing patterns in our educational systems in which "increasingly narrow and specialized job training has displaced a broader liberal education that includes general intellectual and esthetic content" (p. 22). Reading, telling stories, creating art, playing music, acting, meditating, gardening, and physical education are all essential components of a broad curriculum to promote skilled consumption and draw our collective behavior toward sustainable reinforcers. According to Grant, "(t)he recognition that the arts are a potential means of furthering sustainability dramatically reframes education and other public-policy priorities" (p. 36). Arts education programs aimed at improving skilled consumption of resource-light reinforcers are therefore perfectly suitable for inclusion in school-wide sustainability plans such as those promoted by Gibb (2016) and are likewise amenable to effective instructional frameworks such as the Scientist Educator Model (Newsome et al., 2021) or the Model for Generative Instruction (Johnson & Layng, 1994; Johnson et al, 2021), for example.

The maximization of our educational system to produce skilled consumers can be envisioned as a catalyst for change in the global economy and the policies that regulate it. A current barrier to regulatory progress is that fighting environmental regulation is a core competency of global corporations and industry groups supplying unsustainable goods and products. In 2016, U.S. companies spent over $3B on lobbying expenditures (Rivera & Patnaik, 2017), and the biggest polluters spend the most (Delmas et al., 2016). The collective demand for unsustainable products undermines political efforts to stem their supply. However, lessening the future demand for such commodities is achievable if today's students are provided with the skills needed to establish sustainable reinforcers. The creation of skilled consumers is a critical catalyst to advancing pro-environmental regulatory and economic conditions. Notwithstanding the many available policy recommendations for regulating the supply of resource-heavy commodities, our focus here is on the role of educational systems in shaping the forces of economic demand in a sustainable economy.

Delmas et al.'s (2016) analyses of corporate lobbying expenses related to environmental policy revealed a U-shaped curve in relation to corporations' environmental performance, indicating that the group of organizations spending the most on lobbying comprised both the dirtiest and the cleanest. Their investigation showed that the cleanest corporations found a competitive edge by spending to advance pro-environmental policy (see also Rivera & Patnaik, 2017). By being "greener," those companies could gain faster access to newly regulated markets, benefit from a pro-environmental reputation, and suffer fewer compliance costs than their environmentally adversarial competitors. If our public schools can produce socially conscious skilled consumers, greater economic demand will be reallocated toward resource-light commodities. In response, we can expect corporations to act in their best financial interests by accelerating the trend of pro-environmental corporate advocacy in accordance with changing consumer demand and relative market competitiveness.

Discussion

The negative externalities observed in the COVID-19 pandemic have striking similarities to those expected, and already observed, from climate change. Similarities include learning loss due to school disruptions, inequitable impacts among low-income and minority families, resource scarcity, declines in mental health, and vast economic impacts, to name a few. Given the likenesses of these problems, the actions needed to update our teaching methods to withstand the next pandemic have considerable overlap with those needed to adapt our teaching methods to climate change. Additional resources made available to educators as a result of COVID-19 can be directed toward adopting new instructional models which both serve the primary purpose of catching students up from pandemic learning losses as well as increasing resilience to foreseen climate crises. Well-developed models of behavioral education not only support faster acquisition of standard academic skills like reading and math, but also serve as a framework for the design of new curricula. New learning objectives for consideration in a revamped education system include a wide range of climate change related topics and projects, skills for the consumption of resource-light commodities, analytical skills to judge the validity of information objectively, and exercises to improve students' readiness to successfully learn remotely when schools inevitably close for natural disasters.

Installing PT, DI, CBM, etc., as standard operating procedures in all public classrooms would also represent a significant step toward a more equitable education system. Although academic outcomes for nearly all students could be improved, schools in the poorest communities with the lowest-performing students stand to gain the most from these changes. As evidenced by (Sawyer et al., 2021), when provided with effective instruction, students in even the most impoverished learning environments can make gains exceeding those in the most exclusive preparatory academies.

The sustainable future we seek rests upon an education system that works. An education system that works will re-establish upward trends in academic attainment and can teach students remotely, if needed, without learning loss. A working system innovates ways to incorporate climate change across subject areas and provides students with opportunities to engage in hands-on projects to improve sustainability. It produces informed students who foster a familiar culture of sustainability. Those students become adults aware of how their actions impact our ecosystem. Long-established, resource-light reinforcers will maintain their behavior, and they will have the skills to enjoy them thoroughly.

This manuscript reviews the likely impacts of climate change on schools and educational systems globally. Many expected disruptions are similar to those observed during the ongoing COVID-19 pandemic but differ in our ability to rapidly inoculate against them. Recommendations about how we can collectively respond to and mitigate these risks include: (1) upending the status quo of pedagogical approaches toward the adoption of more efficient empirically supported instructional models, (2) creating and implementing a curriculum to establish the skill sets needed for students to effectively learn remotely when needed, and (3) capitalizing on the power of an effective educational system as a catalyst for innovation, consumer-led policy reform, and cultural transformation with respect to how climate change is understood and acted upon. How, where, and what we teach *will* change due to anthropogenic global warming. Our choice now is whether that change will be one of intentional design or one passively inherited at the effect of circumstance.

Data Availability No novel datasets were generated for this manuscript. Sources of all data analyzed for this manuscript are found in the references section.

Declarations

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