THE CASE FOR K12 SYSTEMS-BASED URBAN RESILIENCY CURRICULUM

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ABSTRACT

The objective of this research was to develop a K12 curriculum that engages youth on the topic of sustainable and resilient future cities. To demonstrate how using the city as context enables the fusion of standard K12 disciplines and cross-cutting ideas, a systems-based framework that encompasses both natural and human elements was created. Typical K12 standards were outlined using the example of USA national curricula for middle-grades and these were mapped back to the city framework. To better understand the emerging trends in environmental or sustainability education, a systematic survey of existing curriculum offerings for these topics was conducted. The results were organized by predominant subject themes and then located within the context of the sustainable and resilient city. To develop a cohesive curriculum delivery format, examples from current curriculum design practice were studied. Because of the dynamic and interdisciplinary nature of the topics involved, a combination of existing curriculum design frameworks were used, primarily drawing from the Institute of Play, Understanding by Design, Partnership for 21st Century Learning, and Systems Thinking.

The result was a five-phase modular nine-week course using a game-based mission/quest format as the primary delivery method, which also enabled the activation of systems-thinking, inquiry and project-based learning. Students embark on a global quest-based journey creating teams and knowledge to build an adaptive and resilient city for a particular geographic location around which the themes and standards identified during the research phase were organized using the following format: 1. Values 2. Big Ideas 3. Designing 4. Adaptation 5. Your City Story. As of this writing the curriculum was being piloted in middle-grade science, social studies and environmental education classes around the world. Data was being collected to test its efficacy.

Key Words: Anthropocene, Environmental Education, Resilience, STEAM Education, Systems Education

INTROUCTION

The impact of human habitat on the Earth's dynamic balance is undeniable, as is the need to facilitate education encouraging a paradigm shift about how we inhabit this planet. One excellent opportunity to impact our collective future is through youth education programs focusing on the built environment. This paper describes the development of a K12 curricular framework which integrates traditional K12 subjects like geography, environmental science, social studies, science and math while also preparing youth to proactively imagine, design and build our resilient and adaptable future.

PURPOSE

Most K12 school systems Europe and North America are still operating on models developed in response to the Industrial Revolution. These systems were designed to ideally prepare urban citizens for repetitive and predictable work. [1] But today society is faced with another challenge, namely preparing for a future where we are increasingly forced to plan for and react to events caused by the anthropogenic influence on our collective "home", Earth. This includes climate change, misuse of resources and dwindling biodiversity. Increasingly, there is a call for a paradigm shift in how we educate our youth. Sir Ken Robinson said that "..the new and urgent challenge is to provide forms of education that encourage young people to engage with global economic issues of sustainability and environmental well being - to encourage them toward forms of economic activity that support the health and renewal of the world's natural resources rather than to those that deplete and despoil them." [2] This recognition of the need for evolution in our pedagogical structures provides an opportunity to embed new models embracing responsible stewardship of our collective "home".

QUESTIONS

This paper argues that using the city as a framework for part of this new pedagogical model can promote engagement, incorporate K12 knowledge standards and also help develop responsible stewards of our future. To create this framework, research was directed around the following questions:

- How could using the design of resilient cities and our built environment be the context to promote responsible change?
- How does using the city as a learning context enable the fusion of disciplines and cross-cutting ideas?
- Apart from K12 Standards, which education content themes are relevant to the study of sustainability, resilience and the city?
- Which curricular frameworks and themes are useful for inspiring sustainable thinking while providing the ability to incorporate K12 standards?

SIGNIFICANCE

In 2015, the United Nations General Assembly issued a blueprint for achieving a more sustainable future for the world through its 17 Global Sustainable Development Goals (SDGs) for 2030. [figure 1] Taking Sustainable Cities and Communities (#11) as an example, it becomes clear that the 17 SDGs are integrative in nature and should not be viewed in isolation. How are Sustainable Cities and Communities achieved? Through (#9) suitable infrastructure, where (#6) clean water and sanitation are available, using (#7) renewable energy, whose citizens practice (#12) responsible consumption in a circular economy. And land use is planned to preserve the biodiversity on land (#15) and (#14) below water.

figure 1: UN Sustainable Development Goals. Retrieved from: https://www.teachsdgs.org

In the book EarthEd, the case for creating more holistic K12 programs is outlined using examples and perspectives from around the world. "But many new educational priorities must emerge: ecoliteracy, moral education, systems thinking, and critical thinking, to name a few. Without these and other key skills, today's youth will be ill-equipped for the dual challenges that they face of building a sustainable society and adapting to a changing planet." [3] The Project for 21st Century Learning, another future-oriented framework in wide-spread use, does include the environment as a key element but is shy about directly naming significant issues for our future like climate change. [4].

Despite both the powerful influence of cities and the large challenges they will face in the future due to any number of changes, there are few K12 programs which use the city as a context to teach these complex issues through relating back to K12 standards in science and social studies. Yet, according to Kent Larson of MIT Media Lab's City Science Group, 90% of all future population growth will be in cities, cities will account for 80% of global CO2 production and 75% of energy use. "For all these reasons, the great challenges of our era, whether climate change, food, health, water, equity, peace, jobs, can best be addressed in the context of cities." [5] Humans will only survive if we change and adapt, and it would be irresponsible not to bring this focus to global K12 education.

While there are some existing programs in use [table 1] there are none that use *the city as context* around which to organize K12 standards delivery, despite the majority of us being part of a city system in some significant form. The city, when viewed as the intersection of both natural and human elements, is the ideal context around which to build relatable, engaging, educational content empowering youth towards a resilient future.

name	subject area	audience	highlights	gaps
FutureCity [6]	engineering design	K12 middle grade	project based learning, yearly competition	not systems- or sustainability focused, no scale or geographic reference
GlobalCities Inc [7]	global learning competencies	K12 middle grade	school focused	limited in scope, no STEAM/STEM
EcoSchools [8]	interventions across school systems to encourage sustainability	K12 schools	facility based, focused on behavior change	not project based, not integrated with STEM, no spatial reference,
TeachSDGs [9]	Resources for teaching UN2030 Sustainability Goals	K12 schools	global platform to address sustainability	need context and system to relate each SDG
MIT City Science City Scope [10]	urban planning for future cities	university	interactive, data focused	neglects connection between human and natural environment
Center for EcoLiteracy [11]	ecological education, systems change, sustainability	K12 and general audience	catalog of short lessons	short lessons, no project or systems based learning

table 1: Highlight of programs touching on sustainability, resilient cities and education

METHODOLOGY

As Architects, Urban Planners, Geographers, Curriculum Designers, Educators and Systems Engineers, this interdisciplinary research and design team was aware how the city enables the fusion of disciplines and cross-cutting ideas. And much of this content can be mapped back to science and social studies taught in K12, particularly in middle-grades. In other words, the *city provides relatable context and a forum for engagement* around abstract concepts like resilience, adaptation, and sustainability.

Three components of the initial curriculum design premise were that:
-Systems-based education is needed to increase awareness of ecosystems, interconnections and to develop comfort with modeling.
-Increased awareness of the interdependence between natural and built environments is needed to develop sensibilities about lifestyles, resource use and consumption.
-The best opportunity for reaching and inspiring a young audience and make life-long impact is to provide them with hands-on, inquiry based and student-led learning.

To test the above and design the curriculum, research was focused on the following three questions:

1. **How does using the city as context enable the fusion of disciplines and cross-cutting ideas**

"One of the foundations of deep learning is systems thinking. Understanding that the world is made up of interconnected, nested systems, many of which follow similar rules, is key to fully grasping the challenges ahead." [12]

With the objective of making clear how seemingly disparate subjects found within the context of the city are in fact related through logical and tangible systems, a systems-based framework was created. [figure 2]
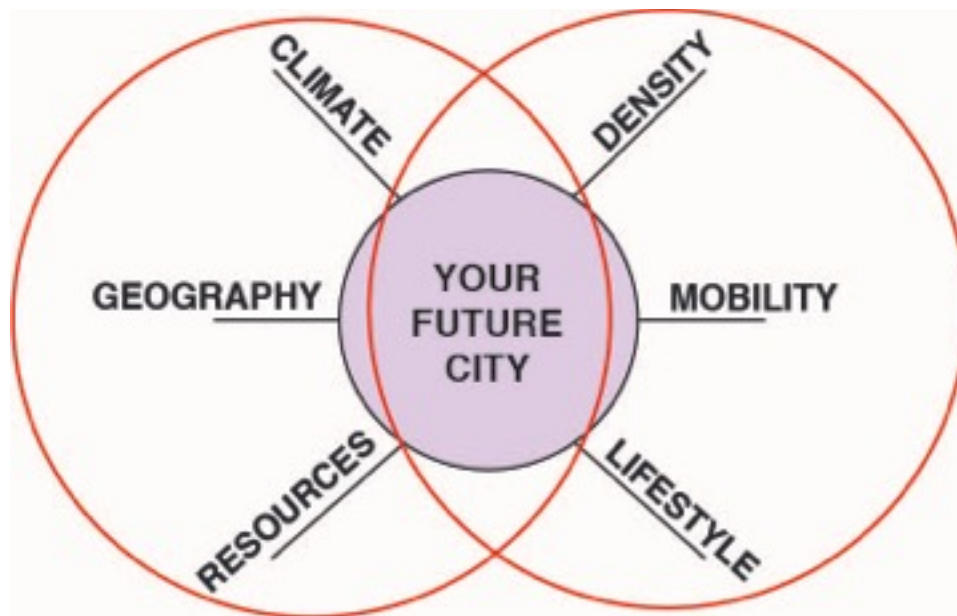

figure 2: HS UrbanEngineers framework showing overlap of natural and human factors

In this framework, the city is a system represented as the intersection of natural and human elements. Natural elements are grouped by Geography, Resources, and Climate. Human elements are grouped by Density, Mobility and Lifestyle. Because sustainable and resilient cities are about a delicate interaction between these natural and human elements, like gradients along a spectrum of informed choices to be made, this framework becomes a thought model to test possible scenarios. At the same time it is easy to map typical K12 course work like physical geography, earth science, biology, human geography, engineering, back to ideas represented within this system. [figure 3]

Table 2 identifies sample standards from the USA national curricula to which content from this integrated study of cities can be mapped. In most cases, the standards identified include opportunities for interdisciplinary linkages and systems-based learning. For example, the Next Generation Science Standards (NGSS) uses Crosscutting Concepts to signal linkages within broader learning outcomes. The C3 Framework for Social Studies uses Inquiry Arcs to structure learning around the physical, spatial, historical and human components of Geography. Similar Inquiry Arcs are outlined for other Social Studies subjects.

figure 3: UrbanEngineers Systems Wheel showing gradient of possibilities and choices for the Arid City and how these can map to K12 standards

The Partnership for 21st Century Learning (P21) uses the 4Cs (Critical Thinking, Communications, Collaboration and Creativity) to encourage cross-disciplinary outcomes.
The North American Association of Environmental Educators (NAAEE) created their Guidelines for Excellence in Environmental Education (EE) by identifying where EE subjects are already present with existing science, social studies standards.

example (US)	subjects	organizing concepts
NGSS [13]	science - physics, chemistry, biology, earth and env science, engineering design	Science and Engineering Practices, Disciplinary Core Ideas, Crosscutting Concepts, Connections to DCIs https://www.nextgenscience.org
C3 Framework [14]	Social Studies - physical & human geography, economics, history, social studies	Subjects focused on preparing for College, Career and Civil Life (C3) to create knowledgable, thinking and active citizens. Dimensions organized around an Inquiry Arc. https://www.socialstudies.org/c3
Common Core [15]	Math and Language Arts	National guidelines on the achievement of college and career readiness in math and language arts for K12. http://www.corestandards.org
P21 Framework [4]	Including 4Cs: Critical Thinking, Communications, Collaboration, and Creativity are included in education to prepare future leaders	"Define and illustrate the skills and knowledge students need to succeed in work and life, as well as the support systems necessary for 21st century learning outcomes." https://www.batelleforkids.org
Teach SDGs [9]	UN Sustainability Development Goals	Educate to the broadest audience possible about the UN SDGs https://www.un.org/sustainabledevelopment/sustainable-development-goals/
NAAEE Guidelines for Excellence in EE [16]	Environmental Education	Highlighting the environmental education concepts within existing standards like NGSS, C3 Common Core https://cdn.naaee.org/sites/default/files/eepro/products/files/k-12_ee_executive_summary_lr.pdf
table 2: K12 Standards Applicable in Study of Cities (example USA)		

2. Apart from the K12 Standards, which education content themes are relevant to study of sustainability, resilience and the city?

The city wheel described in question 1 enables the location of standards within the context of the city. To understand environmental or sustainability education more specifically, a systematic survey of existing curriculum offerings was done. Results were grouped into relevant themes, which can be described as follows and as summarized in [table 3].

The categorization is inspired in part by the prevalence of observed recurring product aims and in part by how content could fit within a city-focused context. Definitions of each category include the following: *Systems Literacy* - Teaching or demonstrating systems concepts; *Environmental Literacy* - Imparting scientific knowledge about specific existing earth phenomena or about our personal / collective impact on environments; *Ecological Literacy* - Teaching or demonstrating concepts about ecology or knowledge about specific ecosystems; *Climate Literacy* - Imparting knowledge about climate phenomena and / or building agency in face of climate change; *Sustainable Design* - Imparting familiarity with design practice/process, modeling sustainable development values or imparting familiarity with sustainable design methods (in the shaping of the built environment); *Circular Econ-*

omy - Imparting understanding of or demonstrating circular product life cycles. While many of these themes are presented through stand-alone short lessons, it is notable that they may be used in interconnected and relational ways when applied in the context of a continual lesson about a city.

theme	purpose and focus	city context - see RESULTS	SDG content	sample content
Systems Literacy	Teach or demonstrate systems concepts	big ideas, adapting, your city story	All	Buck Institute [17], Waters Foundation [18], Linda Booth Sweeney [19]
Environmental Literacy	Impart scientific knowledge about specific existing earth phenomena or about personal/collective impact on environments	values, big ideas, designing	13, 14,15	NAAEE Guidelines
Ecological Literacy	Teach or demonstrate concepts about ecology or knowledge about specific ecosystems	big ideas	13,15	ecoliteracy.org
Climate Literacy	Impart knowledge about climate phenomena and/or build agency in face of climate change.	values, big ideas, designing, adapting	13	ecoliteracy.org
Design Literacy / Sustainable Design	Impart familiarity with design practice/process, to model sustainable development values or impart familiarity with sustainable design methods (in the shaping of built environment).	design your city	6,7,9,11	FutureCity, Global Footprint Network [20], Green School Alliance [21]
Circular Economy	Impart understanding of or demonstrate circular product life-cycles.	design your city, invent a product	6,7,11, 12	Circular Classroom [22], Cloud Institute [23]
table 3: Summary of Research: Environmental / Sustainability Education Curriculum Focus Themes				

3.Which curricular frameworks are useful for inspiring sustainable thinking while providing incorporation of K12 standards?

Although the city wheel described in question 1 is an elegant metaphor around which to organize ideas, themes and standards, it is not a curriculum in itself hence the need to build one that speaks to the inherently interdisciplinary and dynamic process of designing a resilient city. The concepts of change, resilience and adaptation are not static, so therefore require robust but flexible teaching frameworks to deliver content effectively and efficiently.

With much of the content sitting at the intersection of Social Studies and Science as demonstrated in [figure 2], existing curriculum design frameworks like the DBQ Project, [24] the 5E Model [25] and Understanding by Design [26] were investigated. While each represents successful teaching frameworks, none were able to string all the concepts discussed in this paper together in a logical, elegant and engaging way. One curriculum design framework which stood out and which was ultimately adopted is from the Institute of Play (IOP) [27]. The IOP encourages the creation of mission/quest based learning experiences using principles of gaming design. Quests are goal-oriented challenges that equip students with necessary data, knowledge resources and practices to solve the larger mission (learning unit). Often, stories are created around the mission whereby students uncover knowledge and skills as they progress through successive stages of the quest. The mission/quest format also allows for the layering of knowledge standards, promotes student-led learning and is flexible to accommodate other principles like design and systems thinking, which are outside of typical K12 standards. The other relevant frameworks are described below and summarized in [table 4].Understanding by Design method (UbD). UbD is a curriculum design tool that asks to first identify the Essential Questions behind desired learning outcomes and then clarify their Enduring Understandings to provide higher-level context to daily learning. The chief advantage of this method is the promotion deeper, independent and interdisciplinary thinking.

framework	goal	organizing concepts
Institute of Play: mission/quest	Developing game-based curricula.	Play and game-based learning enables high level of student involvement, student-led learning, interdisciplinary learning, deeper thinking.
Understanding by Design	Inquiry-based learning and critical thinking	"Backwards Design": define learning goals and work backwards to plan the lesson by defining "Essential Questions" and "Enduring Understandings" which are more global.
P21 Framework	Ensuring 4Cs Critical Thinking, Communications, Collaboration and Creativity are included in education to prepare future leaders	This framework anticipates the skills, knowledge and expertise students must master to succeed in work and in life in this century; it is a blend of content knowledge, specific skills, expertise and literacies.
Systems Thinking	Think in systems to understand interconnected nature of things	Systems analysis precedes decision making, know the prototypical systems models and apply them to simple cases.
STEM/STEAM	Integrative learning with Science, Technology, Engineering, Math	No prevailing framework or theory, but most incorporate project based learning, design thinking.
table 4: Relevant Frameworks for Curriculum Design		

In addition to the cannons on systems thinking from D Meadows [28] [29], Linda Booth Sweeney [30] and resources from the IOP were referenced to understand systems thinking applications in K12 education in general and in climate change education in particular because "…systems thinking means understanding a system by examining the linkages and interactions between the elements that compose the entirety of the system." [31] Systems thinking exercises should be part of the decision making process usually performed during the information-gathering and analysis phases.

The Partnership for 21st Century Learning is based on the idea that education needs to prepare our youth to proactively shape our future. It stresses the "4 Cs" - Critical Thinking, Communication, Collaboration, and Creativity around topics such as civics, environmental literacy weaving these around 21st century interdisciplinary themes into key subject areas:
•   Global Awareness
•   Financial, Economic, Business, and Entrepreneurial Literacy
•   Civic Literacy
•   Health Literacy
•   Environmental Literacy
The main reason this model is referenced is because it focuses on equipping youth for future challenges and is widely used.

The North American Association of Environmental Education (NAAEE) in 2015 identified how Environmental Education topics map to K12 standards like C3 Framework and NGSS. The resulting Guidelines for Excellence identify the essential underpinnings of en-vironmental literacy and are an excellent reference.

The elements in table 4 are complimentary to the standards frameworks C3, NGSS and Common Core presented in table 2.
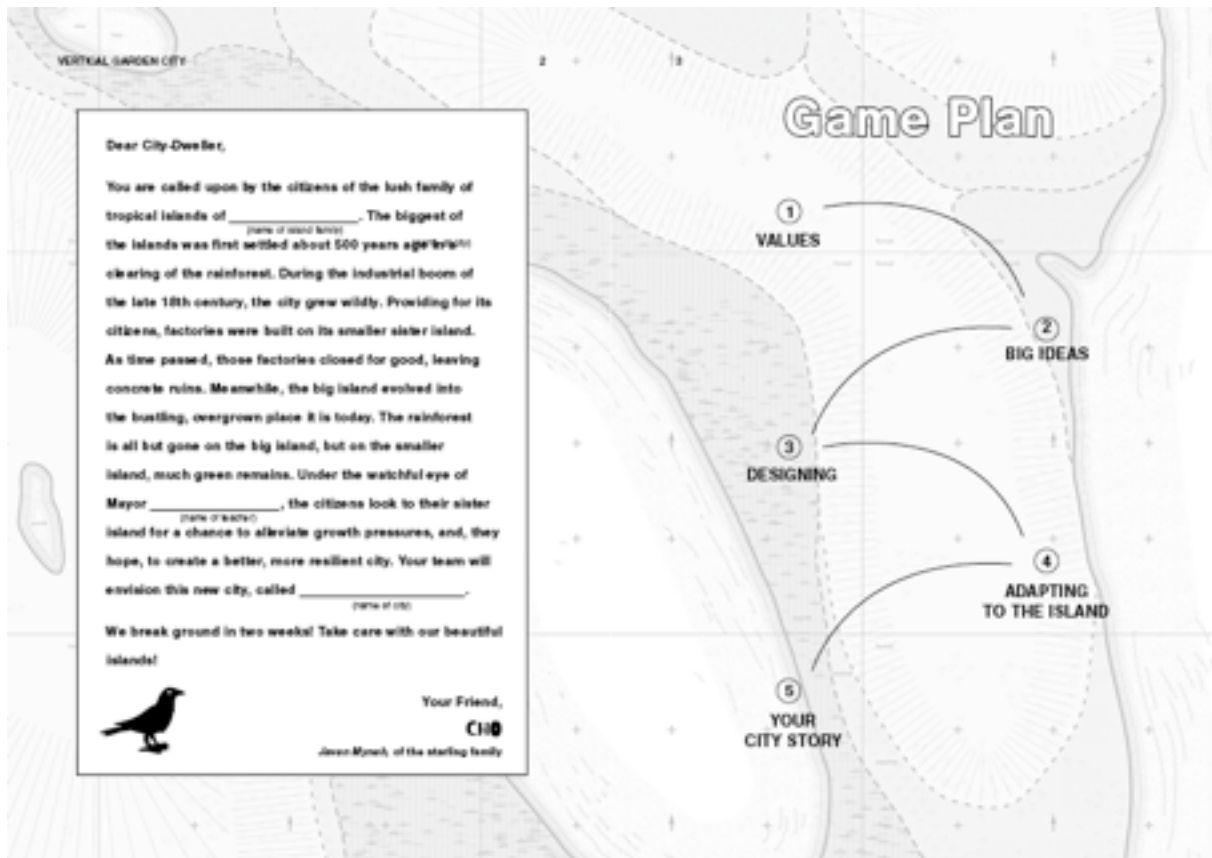
figure 3: sample of UrbanEngineers quest for the Vertical Garden City

RESULTS

The following section describes the coming together of this research into a new framework given the title UrbanEngineers. With UrbanEngineers, students embark on a global quest creating teams and knowledge to build an adaptive and resilient city for a particular geographic location using the following steps: 1. Values 2. Big Ideas 3. Designing 4. Adaptation 5. Your City Story. These phases are described below and summarized in [table 5].

1. Values: The first phase of the quest asks students to situate their needs within familiar contexts. Through exercises like "A Day in My Life", "Self to World" and building their team, students identify needs where they are located with respect to themselves, their community, their city and the world. Themes present in this phase include needs assessment, storytelling, ethics, self-reflection, systems thinking, environmental literacy and climate literacy. Essential Questions include: What is important to me? What are my needs and where do they come from? What are my skills and how am I supposed to use them?
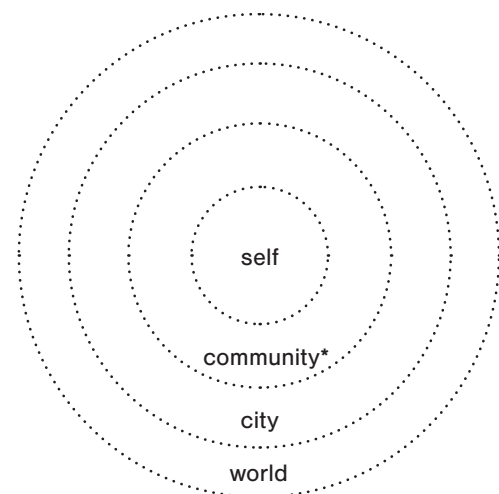
2. Big Ideas: The second phase asks students to identify, define and analyze a system. Starting with a familiar location (their school, the playground, the park next door) students are asked to map their observations and identify challenges. Using collect & cluster, causal maps and story cards, they ask questions about change and learn to use causal maps / feedback loops to analyze choices. Themes presented in this phase include ecological literacy, urban geography, systems thinking, and environmental literacy. Essential Questions include: What is a city anyway? What does a city do? Is it like an ecosystem? How does change happen?

2. Designing: The third phase asks students to research the human and natural contexts for the new city based on a fictive or real map of approx 1.60, x 1.60m, scale 1:200 shared by one class of 25 students. In groups of 4-5, they define its Big Ideas, design adaptive products and finally build together. Using the UrbanEngineers' city wheel explained in figures 1 & 2, this experience provides opportunity for successive analysis and iterative decision making. Themes presented in this phase include design literacy, sustainable design, systems thinking, climate literacy, and environmental literacy. Essential Questions include: What is life like in this location? What might be some of the challenges of living in this location? How can I overcome these challenges?
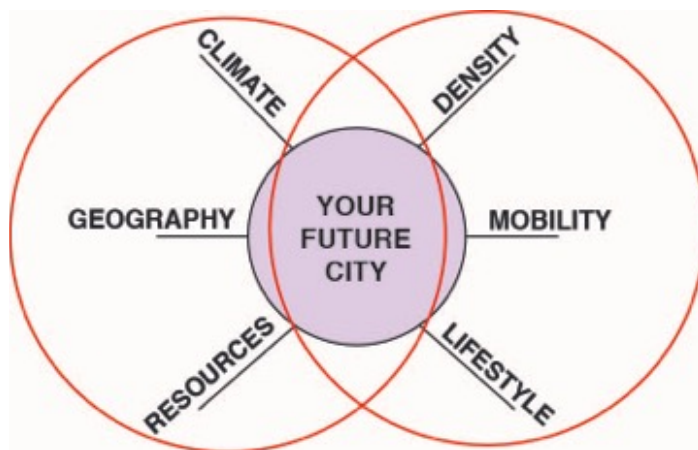
1.Geography: Research the geography of your location, get to know it better, and think about the interplay between your location and how you live.

2.Climate: Research the climate of your location and speculate on how it impacts the way you live. How might your take advantage of these features?

3. Resources: What resources will you need in order to survive and thrive in this habitat? Which resources are available and which are missing?
4. Lifestyle: How is *A Day in the Life* for someone in your budding community? Combining quest format with team and hands-on activities, students spontaneously develop ideas about community. Opportunity to address broader social and behavioral change themes of SDGs. How will these influence the V*alues and Big Ideas* of our city.
5. Mobility: Mobility touches on issues of land use, resource use, access, health, air quality, community and more!
6. Density: Density is an important factor determining land use, resource use and city character. Quantitative and qualitative. What are some elements to think about?
7. City Charter: What are the Big Ideas and Guiding Principles for each element on the city systems wheel?
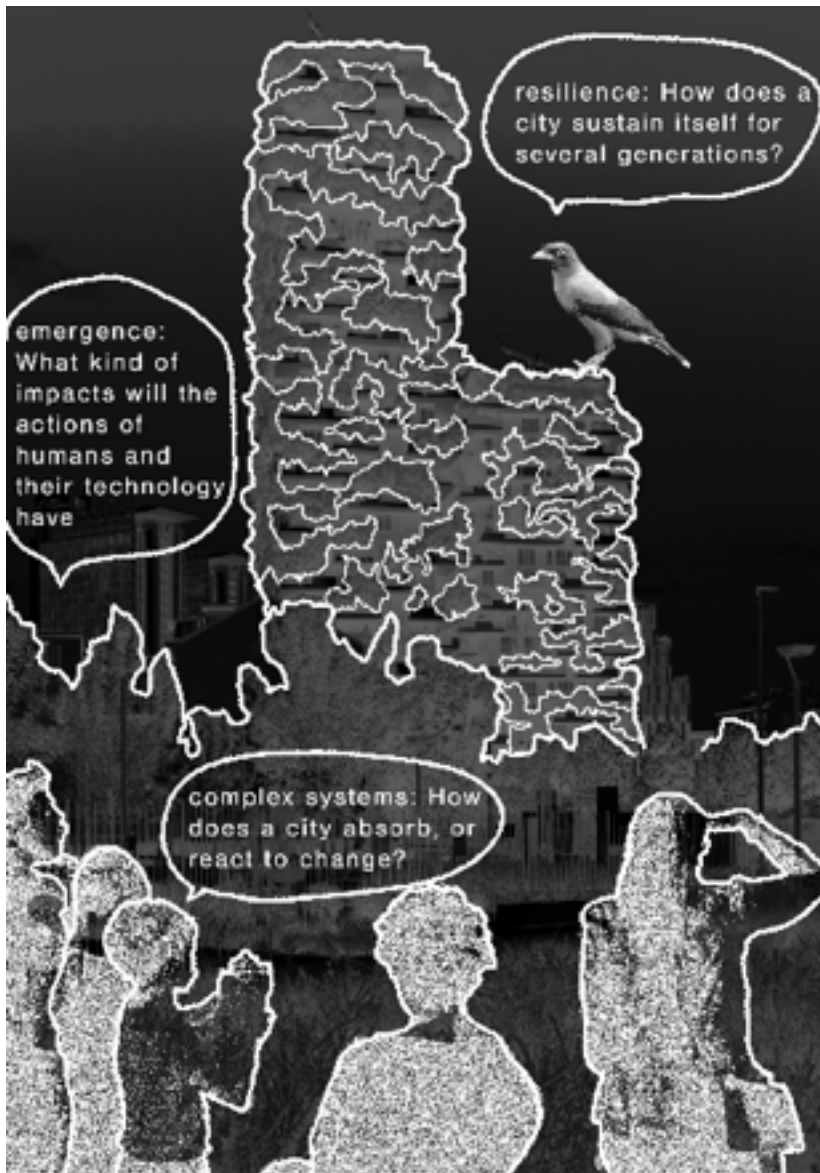
3. Adaptation: The fourth phase enables the chance to put learning onto practice, challenge assumptions and adjust accordingly. Randomly selected "challenge cards" direct critical thinking about choices by simulating real-life, complex issues. How do your Big Ideas and Guiding Principles hold up? Collectively reflect on change and the process of moving forward and test a thought model. Themes presented include design literacy, sustainable design, systems thinking, climate literacy, environmental literacy and social justice. Essential Questions include: How will future generations continue to live at this location, based on actions today? How will people in 30 years be able to sustain themselves?

4. Your City Story: The final phase asks for a presentation using media of choice. How have you designed your city to be resilient? What is it like in or city and how is it similar/different to where you live? What lessons will you bring back home? Themes include communications and media literacy. Essential Questions include: What kind of impacts will the actions of humans and their technology have (emergence)? How does a city sustain itself for several generations (resilience)? How does a city absorb or react to change (complex systems)?

phase	topics	standards / methods (see tables 2,4)	themes (see table 3)
values	needs assessment, visual storytelling, self-reflection, collaboration, team building	IOP, UbD, Systems Thinking	climate and environmental literacy
big ideas	ecology/ecosystems, systems thinking, biodiversity, urban geography, causal maps, feedback loops	UbD, Systems Thinking	environmental, climate, ecological, systems literacy
designing	design thinking, product design, geography, cultural studies, social studies	NGSS, C3 Framework, STEM, engineering design	environmental literacy, climate literacy, circular economy, design literacy, sustainable design
adaptation	risk mitigation, design thinking, adaptive thinking, communications/media studies	IOP, UbD, Systems Thinking, Common Core	climate literacy and systems literacy
your city story	what are lessons you can take back to your home? communications/media studies	IOP, UbD, Systems Thinking, Common Core	climate literacy and systems literacy
table 5: HouseStories UrbanEngineers Framework			

DISCUSSION

Table 5 summarizes at a glance results from the interdisciplinary research outlined in this paper and demonstrates a possible road map for holistic integration of these results in the form of a five-phase K12 middle-grade course. To solidify the assumptions made and to demonstrate universal applicability of approach, four complete courses were designed with this format, using the following extreme climates and geographies as examples:

-The Arid City (inspired from UAE)
-The Floating Coastal City (inspired from Netherlands)
-The Vertical Garden City (inspired from Singapore)
-The Mars City (inspired from NASA work in space)

The phases Values and Big Ideas are designed to teach tools for analysis using familiar locations and situations.
The phase Designing applies the UrbanEngineers city wheel which requires the interrelation of natural and human elements within an analysis and design context. It is applicable across geographies, cultures and even planets.
The phase Adaptations asks the students to re-apply the tools learned in Values and Big Ideas to their own design when confronted with real-world challenges like sudden increase of population, decrease in an important resource, or natural disaster.

The phase Your City Story asks the students to articulate and communicate what they learned.

UrbanEngineers courses are currently being piloted so discussion thereof will be at a later date. Further, important concepts from the work outlined in this paper will be tested with efficacy studies, including the following inspiration from the NAAEE Guidelines for Excellence [16]:

1. *That the curriculum was "fair and accurate in describing environmental problems, issues, and conditions, and in reflecting the diversity of perspectives on them."*
2. *That the curriculum "fostered awareness of the natural and built environment, an understanding of environmental concepts, conditions, and issues, and an awareness of the feelings, values, attitudes, and perceptions at the heart of environmental issues, as appropriate for different developmental levels."*
3. *That the curriculum "built lifelong skills that enable learners to address environmental issues."*
4. *That the curriculum "promoted civic responsibility, encouraging learners to use their knowledge, personal skills, and assessments of environmental problems and issues as a basis for environmental problem solving and action."*

These validation points are in addition to those based on subject-matter knowledge and skills.

CONCLUSION

In preparing our youth for the future challenge of creating resilient and adaptable habitats, the need for new methods of teaching has been identified by multiple experts across the world. Due to the immense impact of human settlement on the planet, a K12 curricular framework that addresses the intersection of natural and built systems is needed. The purpose of this paper was to outline the rationale for a K12 city-based curriculum that can address this topic in an engaging and positive way, as well as to explain the research undertaken to create such a curriculum. The methodological review of existing standards, themes and methods revealed an opportunity to create a dynamic new framework that is inclusive, flexible and encompassing. The primary focus for use is with middle-grade science, social studies, STEAM and environmental education courses, as well as with courses on global citizenship. Additional focus for use is with community-based programs such as camps and after-school programs in a wide variety of settings. Preliminary feedback is that the framework is robust in settings as diverse culturally economic and geographic settings.

REFERENCES

[1] Robinson, Sir Ken & Aronica, Ken. (2016). *Creative Schools: The Grassroots Revolution That's Transforming Education*. NewYork, USA: Penguin Books

[2] Robinson, Sir Ken & Aronica, Ken. (2016). *Creative Schools: The Grassroots Revolution That's Transforming Education*. NewYork, USA: Penguin Books, page 47

[3] The Worldwatch Institute (2017). *EarthEd (State of the World): Rethinking Education on a Changing Planet*. Washington DC, USA: The Worldwatch Institute, page 4

[4] Framework for 21st Century Learning (2019). Retrieved from http://www.battelleforkids.org/networks/p21/frameworks-resources

[5] Larson, Kent (2019). *MIT BSC M1U1 Video 1 Transcript.* Retrieved from https://mit-medialab.onlinecampus.getsmarter.com

[6] 2018-2019 Future City Program Handbook (2018). Retrieved from https://futurecity.org/form/resources?download=/sites/default/files/2018-07/2018-2019_Program_Handbook_hi.pdf

[7] GlobalCities Inc (2019), *2019-2020 Curriculum: Nature and Our Cities*. Retrieved from https://www.globalcities.org/curricula

[8] EcoSchools (2019), *EYFS & Primary Pathway*. Retrieved from https://www.eco-schools.org.uk/eyfs-primary-pathway/

[9] Teach SDGs Instructional Materials. Retrieved from http://www.teachsdgs.org/assets.html

[10] Zhang, Yan (2017) *CityMatrix – An Urban Decision Support System Augmented by Artificial Intelligence* Retrieved from https://dam-prod.media.mit.edu/x/2017/08/23/ryanz-ms-17.pdf

[11] Teaching Resources from the Center for EcoLiteracy (2019). Retrieved from https://www.ecoliteracy.org/resources

[12] The Worldwatch Institute (2017). *EarthEd (State of the World): Rethinking Education on a Changing Planet*. Washington DC, USA: The Worldwatch Institute, page 12

[13] NGSS (2017). *Next Generation Science Standard*s. Retrieved from https://www.nextgenerationscience.org

[14] National Council for the Social Studies (2013) *The College, Career and Civic Life (C3) Framework for Social Studies State Standards*. Retrieved from https://www.socialstudies.org/sites/default/files/c3/C3-Framework-for-Social-Studies.pdf

[15] Common Core State Standards for English Language Arts and Mathematics (2010). Retrieved from http://www.corestandards.org/read-the-standards/

[16] North American Association for Environmental Education (2017) *Guidelines for Excellence Series*. Retrieved from https://naaee.org/eepro/publication/guidelines-excellence-series-set

[17] Buck Institute for Education (2015). *GOLD STANDARD PBL: Project Based Teaching Practices.* Retrieved from https://my.pblworks.org/system/files/documents/PBLWorks%20-%20Gold%20Standard%20Project%20Based%20Teaching%20Practices.pdf

[18] Resources from Waters Center for Systems Thinking. Retrieved from www.watersfoundation.org/our-resources

[19] Resources from Linda Booth Sweeney. Retrieved from http://www.lindaboothsweeney.net

[20] Tools and Resources from The Global Footprint Network. Retrieved from https://www.footprintnetwork.org/resources/

[21] Resources from the Green School Alliance. Retrieved from https://www.greenschoolsalliance.org/resources/category/1

[22] Arcaroglu, Dr Leyla *The Circular Classroom Educator Support Pack.* Retrieved from https://circularclassroom.com/wp-content/uploads/2018/09/EducatorSupport_EN.pdf

[23] Resources from the Cloud Institute. Retrieved from https://cloudinstitute.org/our-approach

[24] Sample Units for the DBQ Project. Retrieved from https://www.dbqproject.com/dbq-project-library/#sample-units

[25] Bybee, Rodger st all (2006), *The BSCS 5E Instructional Model: Origins and Effectiveness.* Retrieved from https://media.bscs.org/bscsmw/5es/bscs_5e_full_report.pdf

[26] Wiggins, Grant & McTighe, Jay (2005). *Understanding by Design (2nd Expanded Edition).* USA: Assn. for Supervision & Curriculum Development

[27] Q Design Pack Curriculum (2017). Retrieved from https://docs.wixstatic.com/ugd/4401d6_11ec4a6eff0c4c178db7ad55aa9910a1.pdf

[28] Meadows, Donella H. (2004). Limits to Growth, The 30-Year Update. USA: Chelsea Green

[29] Meadows, Donella H. (2009). *Thinking in Systems: A Primer. UK: Earthscan Ltd.*

[30] Booth Sweeney, Linda & Meadows, Dennis (2010). *The Systems Thinking Playbook: Exercises to Stretch and Build Learning and Systems Thinking Capabilities*. USA, Chelsea Green Publishing

[31] *Q Design Pack: Systems Thinking, V1.0* (2017). Retrieved from https://docs.wixstatic.com/ugd/4401d6_8057dbb377b448b1904f97b1d78d1ccb.pdf