Spatial Thinking: a powerful tool for educators to empower youth, improve society, and change the world

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***Abstract**: This paper argues that spatial thinking can effect positive change in individuals and society. Spatial thinking plays a role in shaping young people's capacities to learn and to function in society and thus is valuable enough that it should be explicitly taught to learners beginning at very young ages. Spatial thinking, supported by maps and geospatial technologies as appropriate, can be used to create active, participatory, and emancipated youth engaged in spatial citizenship. Modern society will benefit from a spatially literate population with an enhanced understanding of the world as seen through the key concepts of geography: space, place, scale, power, and human-environment relationships. Critical geography education must have the goal of teaching for a better, more just world.*

***Keywords**: spatial thinking; spatial citizenship; learning progressions; geography education.*

Pensamento Espacial: Uma ferramenta ponderosa para os educadores empoderarem a juventude, melhorarem a sociedade e mudarem o mundo

***Resumo:** Este artigo defende que o pensamento espacial pode provocar mudanças positivas em indivíduos e na sociedade. O pensamento espacial desempenha um papel importante de moldar as capacidades dos jovens de aprender a viver em sociedade sendo, portanto, tão valioso que deveria ser explicitamente ensinado aos estudantes desde muito cedo. O pensamento espacial apoiado em mapas e tecnologias geoespaciais apropriados, pode ser usado para criar uma juventude emancipada, ativa, participativa e engajada na cidadania espacial. A sociedade moderna irá se beneficiar de uma população alfabetizada espacialmente com um amplo entendimento do mundo visto através dos conceitos-chave da Geografia: espaço, lugar, escala, poder e relação homem-natureza A Educação Geográfica Crítica precisa ter como meta o Ensino voltado para a construção de um mundo melhor e mais justo.*

***Palavras-chave**: spatial thinking; spatial citizenship; learning progressions; geography education.*

Geographers today are expressing growing interest in the social and political development of children and youth. Much of this concern is the result of the worldwide turn to the right and consequent disquiet about the conditions under which many young people struggle to achieve equality, inclusion, and a sense of personal agency.

Geography educators have shared these concerns but have done relatively little research to explore the ways that learning geography can empower youth to develop a sense of self, social

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responsibility, and to raise civic consciousness. How do geographic knowledge, skills, and practices develop across individuals, settings, and time and how can these understandings be used in transformative ways? In what ways can geography educators, through curricula and instructional materials, contribute to creating societies that appreciate, respect, and capitalize on difference? In what ways can geography educators help their students to become empowered to participate actively in society?

Geography studies the world from two perspectives: the spatial and the environmental (Heffron and Downs 2012). The environmental perspective focuses on the complex interactions between the physical and human worlds in which we live. Infused in the exploration of these relationships is the primary tool of analysis geographers use, considering space. All events take place in space—Earth space—and the relations among people, places, and environments are spatial. They are also dynamic, constantly changing and evolving, influenced by a number of factors, including power and control. Geographers use space to conceptualize the patterns and processes we observe, including key contemporary processes such as urbanization and globalization, hence, the importance of *the spatial* in geography. This is encapsulated in the process of spatial thinking. Developing an understanding of space and taking a spatial perspective as a habit of mind contributes to the knowledge, skills, and attitudes that determine young people's views of the physical and social world (Anderson 1983; Wade 2001; Williams 2001).

This paper explores specific and intentional ways that spatial thinking can effect positive change in individuals and society. First, I examine spatial thinking and its role in shaping young people's capacities to learn and function in society. In the process I intend to make the case that spatial thinking is so valuable that it should be explicitly taught to learners beginning at very young ages. Second, I discuss ways spatial thinking, supported by maps and geospatial technologies as appropriate, can be used to create active, participatory, and emancipated youth. I use the phrase *spatial citizenship* to illustrate how I believe spatial thinking can contribute to a new type of member of society—one with an enhanced understanding of the world as seen through the key concepts of geography: space, place, scale, power, and human-environment relationships. In conclusion, I return to the three questions posed above to envision a critical geography education with the goal of teaching for a better, more just world.

Spatial Thinking

In order to discuss spatial thinking and to examine its role in shaping young people's capacities to learn and function in society, we first must define it. This is, however, not simple or straightforward. Is spatial thinking the same as spatial *ability*? How does one break down specific spatial *skills* that are components of the process of spatial thinking? How do educators operationalize constructs of spatial thinking in order to develop effective teaching strategies, measures of performance, and learning progressions? And how can we then use its definition to make the case that spatial thinking is a valuable life skill that should be taught explicitly in school?

Many geographers and teachers use the definition of spatial thinking suggested in the groundbreaking study *Learning to Think Spatially* (NRC 2006). Specifically, spatial thinking is defined as the use of spatial concepts, spatial representations, and processes of reasoning to conceptualize and solve problems. Following this definition, spatial thinking involves the ability to visualize and interpret data about space that is then encoded and stored in memory (Sinton 2011; Uttal 2000). This definition emphasizes language (knowing and using spatial concepts such as location, distance, scale); being able to understand spatial representations such as maps, graphics, and diagrams; and the application of these to problem solving, both personal and academic. This is related to the development of a *spatial habit of mind.* This is the predilection to think spatially and to apply the skills required to engage in reasoning with concepts of space and visual representations (Kim & Bednarz 2013). This definition is especially useful for educators who wish to make their curriculum and teaching more spatial (Jo & Bednarz 2009).

Psychologists and cognitive scientists have shared a deep interest in spatial thinking with geographers. However, they have focused more on spatial *ability* than *thinking* per se. Linn and Petersen (1985) identified three distinct components of spatial ability: spatial perception, mental rotation, and spatial visualization. Spatial perception is seen as the ability to understand spatial relationships with respect to one's own body, that is, to accurately perceive objects, routes, or spatial configurations. Mental rotation, in contrast, is the ability to mentally and dynamically rotate two-dimensional or three-dimensional objects. Spatial visualization is another discreet skill generally defined as the ability to manipulate spatial information. Specific tests are used to assess each of these abilities but there is little deep understanding of how the skills interact in a holistic fashion.

In an attempt to better conceptualize spatial ability and spatial thinking, Uttal et al. (2013) devised a classification system or typology of spatial skills consisting of two dimensions (Figure 1). The first dimension examines the characteristics of an object and whether one considers the nature of the object itself (intrinsic information), or the nature of the object in relation to other objects (extrinsic information). The second dimension considers the mobility of the object, that is, whether it is static or dynamic, and what happens when the object is moved. These two dimensions establish a two by two matrix of spatial skills at a fine enough grain at which each (intrinsic-static, intrinsic dynamic, extrinsic-static, extrinsic-dynamic) can be measured. Research indicates that these skills are distinct and may not be mutually shared. An individual good at intrinsic-static skills, that is, gifted in visualizing an object, such as an artist, has skills quite distinct from someone, such as a geographer, who has good intrinsic-dynamic skills and is readily able to visualize spatially (Kozhevnikov et al. 2005).

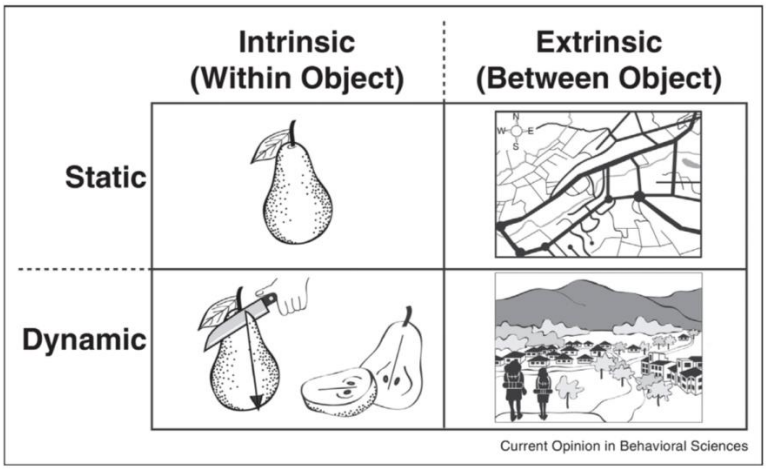

Figure 1: A Typology of Spatial Skills (after Uttall et al. 2013)

While there is some criticism of the Uttal et al. conceptualization of spatial abilities and skills (Newcombe 2016) it still affords us with a detailed way to think about spatial thinking that aligns with the definition familiar to geographers and teachers. And most importantly, this matrix has allowed researchers to understand that spatial skills are malleable, that is, they can be improved, in both women and men, at any age, with permanent and transferable results, and in a range of educational contexts (Uttal et al. 2013). This is important because generally women perform less well than men in many measures of spatial ability such as mental rotation tasks. It further provides geography educators with a detailed sense of the potential *learning progressions* which

pupils may have to master in order to become more spatially skilled. A learning progression is the successive and increasingly complex ways of thinking about a concept mastered when learning that concept (Huynh, Solem & Bednarz 2015).

The Benefits of Spatial Thinking

While there is some ambiguity about the precise nature of spatial thinking, its role in shaping young people's capacities to learn and function in society is more clear. In this section I address two key reasons to care about spatial thinking, one focused on academic concerns and one focused on societal issues.

Academic Achievement. Success in spatial thinking is aligned with success in school. It plays a major role in learning, remembering, and problem-solving. It facilitates the encoding and recall of information, the development of problem-solving strategies, and the transfer of problem-solving skills to new domains (NRC 2006). However, learners' individual characteristics and external contexts influence spatial thinking abilities; these include gender, physical development (age), environmental context, and socio-economic status (SES). Therefore, there is a great deal of interest among researchers and teachers in understanding how spatial abilities develop in learners, particularly, when specific spatial skills first develop, how these skills evolve over time, and what types of interventions and activities promote their development (Hawes et al. 2015). There is concern among geography educators and psychologists that spatial thinking is being neglected in education despite its connections to performance in a range of subjects, including the arts and sports.

One area of research among cognitive and learning scientists focuses on the role spatial thinking plays in achievement in science, technology, engineering, and mathematics, the so-called STEM disciplines. Spatial thinking is correlated with STEM achievement (Liben 2006; Wai, Lubinski, & Benbow 2009). Using spatial concepts and making and interpreting spatial representations like maps and diagrams appears to facilitate the comprehension of STEM concepts (Uttal & Cohen 2012). Spatial thinking, it is thought, may serve as a gatekeeper, or barrier, to access to the disciplines that depend most heavily on spatial skills such as geography and mathematics. This is of special interest to educators committed to widening the participation of traditionally

underrepresented populations such as women and people of color in the sciences, geography, and engineering.

Three key findings related to academic achievement are evident from a review of the literature (Bednarz, Jo, & Shin forthcoming). First, this robust field of intellectual endeavor emphasizes that there are clear developmental stages at which children can—or cannot—complete certain spatial tasks or use spatial concepts (Burte et al. 2017; Geist 2016; Grotzer & Solis 2015; Hawes et al., 2015). Farran and Atkinson (2016) investigated how children aged four to seven represented spatial categories such as *in*, *on*, *under*, *in front*, *behind*, *above*, *below*, *left*, and *right*. They found significant differences in the understanding of children by age, with children progressing through three distinct levels of understanding. Five year olds had adult understandings of *in* and *under*; six year olds fully comprehended *on*, *in front*, *below*, and *behind* while seven year olds still did not have an adult understanding of *left* and *right*. This developmental effect is relevant especially in mental rotation tasks. Cheng and Mix (2014) provided six to eight year olds with practice activities in mental rotation then tested their mathematical abilities. Spatial training did enhance student performance, with greater gains in older students.

Another example of the role of development in spatial thinking is provided by Grotzer and Solis (2015) who examined how students in three grade levels (grade 2, about 7 years old, grade 4, approximately 9 years old, and grade 6, around 11 years of age) understand causes and effects that are separated both in physical and attentional space—a concept they termed *action at an attentional distance*. This topic is of special interest to geography educators who teach about global systems and issues in which causes are physically distant from the effects. These concepts are vexing to young learners who struggle to integrate things they cannot see, or *attend* to, with things they can, yet geographic literacy requires learners to be able to reason across spatial scales and environmental systems to understand causal relationships. Grotzer and Solis used a series of tasks, observations, and interviews to find that when explaining causes and effects across spatial scales, younger learners tended to use local explanations for phenomena rather than distant causes. Further, the grade 2 students anthropomorphized phenomena more than the older students and used naïve and personal anecdotes in their explanations. In addition to these developmental effects, Grotzer and Solis found that a grasp of science concepts, acquired across grade levels, and learning the specific processes at work behind these tasks, for example, understanding the water cycle, aided in thinking across spatial scales. Importantly, they saw that it was possible to mediate age differences in performance and understanding if students were given

explicit training to be aware of attentional frames and to consciously zoom in and out across scales of analysis.

A second finding is that spatial thinking is enhanced by spatial activities, playful learning, and the use of spatial language. Spatial games such as block building and assembling jigsaw puzzles are often accompanied by spatial language (Jirout & Newcombe 2015; Marcinowski & Campbell 2017), which, in turn, is often accompanied by speech-associated gestures (Goldin-Meadow 2015; Sauter et al. 2012). Gestures such as pointing or using one's hands to explain locations play an important role in observing and explaining spatial relations (Goldin-Meadow 2014). Games provide crucial informal learning activities for children, and spatial game play, as well as playing sports, has been found to relate to the development of spatial skills (Ness & Farenga, 2016; Resnick et al., 2016).

A third related and significant finding is that learners of any age can improve their spatial thinking skills with explicit activities. Cohrssen (2017) and colleagues developed a program for kindergarteners (5 year olds) to explore understandings of two- and three-dimensional shapes and spatial thinking with the goal to enhance their mathematics skills. They intentionally embedded multiple opportunities for children to work with shapes and spatial thinking in a problem-based context that included geography-related activities such as mapping the route from home to school and comparing and discussing maps. They found that repeated use of spatial concepts and related language enhanced young learners' spatial orientation and visualization skills, as well as their ability to use mathematical language.

Borriello and Liben (2017) studied the effects of making mothers of preschool children (ages four to six) aware of spatial thinking and strategies to encourage it. The mothers in the experimental group learned about spatial thinking, its importance in daily life (wayfinding in new environments, packing a car trunk, assembling furniture using diagrams) and academic success. They also received training in how to engage with their child to develop spatial thinking skills. The mothers then played with their child with jigsaw puzzles, LEGO pieces in a free play situation, and in a structured LEGO building activity. The control group mothers simply played with their child using the same three activities. The mothers in the experimental group were found to use more spatial language in all three activities and the children also used a higher percent of spatial language, thus indicating that mothers were able to encourage, support, and develop their child's spatial thinking. The authors of the study concluded:

> …this study provides a proof of concept that mothers who are given brief, general instructions about spatial thinking are inspired to offer more spatial guidance to their children than they normally would…the findings offer encouragement for designing, implementing, and evaluating programs targeted to parents with the expectation that they, in turn, can foster their children's spatial skills (Borriello & Liben, 2017, 13).

This last finding is important because, as noted, a number of individual features such as gender, physical development, and socio-economic status influence spatial abilities. Knowing that interventions are successful in closing a spatial thinking-SES and gender gap is significant. It clearly shows the way forward for educators.

The Case for Teaching Spatial Thinking

As we have seen, the evidence suggests that spatial experiences improve learners' mastery of spatial language, their understanding of key spatial concepts, and lay the foundation for future academic and professional success, particularly in highly spatialized fields such as engineering, science, and mathematics. The implications of the findings on the usefulness of spatial thinking for educators are far reaching and obvious—there is a clear relationship between spatial ability, spatial skills, and spatial thinking and achievement in mathematics, engineering and the sciences such as geography as well as other career and workplace fields. Further, the strategies learned through spatial thinking play an important role in other academic activities such as reading and problem solving (NRC 2006; Hegerty 2010). Thus, it is vital that spatial thinking be incorporated into school curricula, instructional materials, and classroom experiences. This should not be considered an add-on to an already full curriculum but rather as a necessary foundation to building intellectual capacity in learners.

The work of Uttal et al. (2013) makes clear that spatial thinking is something that can—and should—be learned. Several of the studies reviewed above confirmed the positive effects of deliberate spatial education. Incorporating spatial experiences in formal settings, like schools, and informal settings, such as play groups and at home, will benefit *all* children. However, learners who because of socio-economic status, gender, and physical development, may be less spatially-abled, will benefit most from opportunities to develop spatial abilities. It is both an ethical and moral imperative to develop the spatial abilities of learners in order to allow them equal access to academic opportunities.

The question then becomes how to go about teaching spatial thinking. Newcombe (2016) suggests three ways to address the issue of spatial learning in formal educational settings: (1) enhance

students' spatial abilities beginning in their infancy; (2) prepare educators to become effective spatial teachers; and (3) spatialize the curriculum. Enhancing *what* is taught and *how* it is taught is the challenge to improving the quantity and quality of spatial learning. Returning to the definition of spatial thinking as the use of spatial concepts, spatial representations, and processes of reasoning to conceptualize and solve problems (NRC 2006), it appears that one concrete strategy is for teachers to become aware of their use of spatial terms and concepts and to encourage young learners to develop their own spatial language skills. This can take place in many contexts, including direct academic lessons, and through play. Playing with blocks, exploring environments, real and imagined, and talking about these experiences are concrete strategies based in research that will spatialize pupils' learning and build an awareness of space.

Talk is aided by gestures, which can show spatial relations visually (Goldin-Meadow 2014). Moving our hands as we explain something is natural, particularly when discussing things that are spatial, such as when giving directions. Gestures both display what an individual knows and can assist in new learning. Younger pupils use gestures less frequently than older learners so explicit instruction in the use of gestures can help to nurture thinking and problem-solving in early years. As Goldin-Meadow explains,

> Gesturing allows learners to take ideas that are not inherently spatial and lay them out in space, thus "spatializing" them. The learners can then make use of spatial mechanisms that they would not necessarily have used had they not gestured (2014, 5).

Geography educators should be encouraged to be aware of their own gestures and to consider effective ways to display concepts using their hands. At the same time, they should encourage students to use gestures, particularly when explaining a problem or a process. This may help to clarify a students' ideas about a topic.

While geography educators are attuned to the use of maps, diagrams, and other spatial representations, other teachers may not be. Geographers know that it is just as important to read and interpret a map (or diagram) as to read text and that this is a skill (or set of skills) that is a challenge to teach. All educators should be led to understand that learning to read visuals is as important as reading text, and that coordinating both will aid in students' development of effective learning strategies. This is true for dynamic representations and animations as well as static graphs. Young learners should be encouraged to create their own visuals to communicate their understandings of spaces and places. Sketching draws learner attention to space, can

encourage the use of spatial language, and may also be used as an assessment tool for educators to measure student understandings and perceptions. A study by Cole et al. (2015) showed positive results in spatial visualization skills following an activity in which students, aged around 11 years, kept daily moon observation journals. Such findings may be true for other detailed environmental experiences in which spatial drawing, language, and observation skills are developed.

A rather obvious strategy to enhance spatial thinking is to actively engage young learners in the physical world in which they live. Developing observation skills (and spatial language), mapping and drawing the world they see, interacting physically and having experiences in the world all will assist in making students aware of space, spatial relations, and the geography of the places they know. Active learning is based on the idea that an effective teaching strategy is to move a learner from *doing* to *knowing*, that is, along a continuum from action to abstraction (Newcombe 2016). Teachers can also model spatial habits of mind (Kim & Bednarz 2013) using think-aloud protocols in their discussions of issues. Reinforcing students' burgeoning spatial understandings by acting as a spatial ambassador may be an effective strategy, but one which needs to be examined through research. Geography educators can take a role in helping their peers to develop spatial habits of mind to infuse such strategies across a school. Geist (2016) lists a number of activities to support spatial thinking abilities, including having learners use maps in daily life; encouraging pupils to identify and use landmarks to describe where things are located using spatial language such as near, before, and after; and giving students frequent opportunities to visualize and present their spatial understandings through drawings, sketches, and maps.

Educators interested in developing spatial thinking skills may wish to consider how children *progress* in their learning. Research in learning progressions confirms the utility of analyzing concepts and developing staged benchmarks through which to develop a particular understanding, skill, or conceptualization (Huynh et al. 2015). The framework for spatial skills presented by Uttal et al. (2013) may serve as a mechanism through which students are moved in considering space and spatial relations. Asking learners to attend to intrinsic static relations first, then expanding to intrinsic-dynamic and extrinsic relations may be a logical process to hone spatial thinking, an idea that should be researched. Another way that geography educators can facilitate students' practice of spatial thinking is to use questions that can stimulate their spatial thinking. A taxonomy of spatial thinking (Jo & Bednarz 2009) can be useful for this purpose.

To sum up, spatial thinking is a powerful tool that is linked to academic achievement and valuable careers and workplace opportunities. It can be taught and learned and I have suggested some

ways that can be accomplished. But what more can spatial thinking offer young people and our society?

Societal Needs and Spatial Citizenship

Geography has been called, "the art of the mappable" (Haggett 1990). This is now true more than ever. There is wide and increasing interest in maps, mapping, cartography, and visual communication in the discipline of geography and in popular and social media; people increasingly communicate through spatial representations. The websites of major news outlets like the New York Times, CNN, Folha de S.Paulo**,** or the Guardian are filled with rich, visually sophisticated presentations on issues ranging from shrinking ice caps to the best ways to display election results. Geospatial technologies such as geographic information systems (GIS), Remote Sensing, global positioning systems (GPS), and associated mapping technologies have exploded in use. The combination of these technologies with social media has changed how we live. Enormous quantities of digital geographic data are available in real-time. We are monitored on closed circuit television systems; we check in to let friends know where we are through apps like Facebook; our smartphones and watches track our physical activities and locations and tell us how to navigate in real space and in real time. We express our opinions on a range of issues frequently through social media and other sharing applications. Who we are, where we are, what we do, and how we feel is shared in geographic contexts. The world is at everyone's fingertips, 24-7 (Downs 2014). This new and evolving, hyper-connected world is changing society and individuals as members of society. It is also affecting our roles as citizens and at a range of scales.

Underpinning the growth in visual communication and geospatial technologies is spatial thinking, in particular, a specialized form of spatial thinking termed *geospatial thinking.* Geospatial thinking is the application of spatial thinking in the context of using geospatial technologies (Baker et al. 2014). Both spatial and geospatial thinking are used simultaneously and in a reciprocal fashion during the use of geospatial technologies. Using a technology such as a GIS can improve spatial thinking abilities; at the same time, learning to think about the world through the mediated perspective that technologies provide affects geospatial thinking and its development (Uttal 2005). Our interaction with technologies is shaping the ways we see, think about, and understand the world in which we live. It is also having an effect on how we engage as members of society.

Geographers, leaders in the use of geospatial technologies, are thinking about the challenges and opportunities for educators to take a leadership role in preparing the next generation of geospatially-literate members of society. This has led to new thinking about the contribution of spatial thinking and geography education to developing young people to be *spatial citizens*. In using the term *citizen* I do not ascribe any legal or formal meaning; I simply use citizen to indicate a member of a society. In the United States and in Europe (Schulze, Gryl & Kanwischer 2014) there are numerous, competing definitions of citizenship and conflicting goals used to prepare young people to be active and engaged members of society.

In the US education system, civics education is a driving goal for social studies education of which geography is a part. Some have questioned the role that geography educators can and should play in civics education (Stoltman 1990). The *National Geographic Standards: Geography for Life* (Heffron & Downs 2012) attempted to change that position by firmly making three points: that geography education's goals are aligned with the goals of citizenship education; that geography has something significant to contribute to citizenship education; and that a promising approach is through actively *doing geography.* Through geographic inquiry, encapsulated in five fundamental skills (asking geographic questions, collecting geographic information, organizing geographic information, analyzing geographic information, and answering geographic questions), young people can learn to make informed decisions in, for, and about society. Such active, inquiry-driven learning experiences are student-led, authentic, and set in the places where students live their lives, thus helping them to develop their unique civic identity. This is the goal of spatialized (geographically-enhanced) citizenship.

The skills of geography have since been revised and re-conceptualized as the *practices* of geography. The term *practice* better captures the complexity of the behaviors that comprise authentic geographic inquiry and problem solving (Bednarz, Heffron & Huynh 2013). A central concern for geography educators, thus, is designing ways to support students in acquiring and exercising these practices to do geography in active and authentic ways to support responsible citizenship. In summary I assert that citizenship, however defined, is inherently spatial and recognizing that relationship enables productive and positive engagement with important societal issues such as equity, justice, and environmental stewardship.

A particularly productive way to move forward is through geospatial technologies and social media. The increased availability of such technologies has enabled youth new ways to participate in democratic practices (Gordon, Elwood & Mitchell 2016; Schulze, Gryl & Kanwischer 2014;

Schlemper et al. 2018). In the next section, I examine a model to prepare young people for civic engagement and suggest a few venues through which spatialized citizens can be developed. These venues fall into three categories: interactive mapping sites; volunteered geographic information (VGI) initiatives; and citizen science projects. All allow young people to hone their spatial thinking skills and capitalize on the spatial narratives they use to understand their worlds. A spatial narrative is the way individuals perceive places, expressed as the stories they tell to understand places. Spatial narratives are developed through both direct and indirect experiences and shape individual's feelings of inclusion, exclusion, and worldview.

A Model for Geospatially Enhanced Citizenship

Much of the discussion about citizenship education focuses on what young people do not know, cannot do, and do not care about. This emphasis on *deficits* does not provide guidance to educators about what to do to move students forward (Mayes et al., 2016) The psychologists Watts and Flanagan (2007) propose a model based on research in liberation psychology, developmental psychology, and youth activism that focuses on *assets* that promote sociopolitical development and hence, civic engagement.

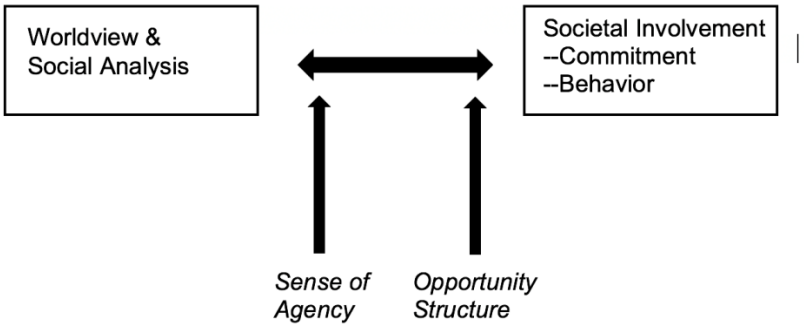

Figure 2: Model of assets to promote civic engagement (after Watts & Flanagan 2007)

The four components of the model are worldview and social analysis; sense of agency; opportunity structure; and societal involvement behavior. A critical consciousness is central to an individual's worldview and ability and proclivity to conduct social analysis. Developing a sense of agency, empowerment, and efficacy in young people is a second component of the model. Efficacy means

a person feels that she or he can *make a difference* at a range of scales: personal, collective, and political. The settings, places, contexts, and resources available for action—the opportunity structures--play a key role in presenting young people with the opportunities to learn how to engage with their communities. These can be in schools, through formal education experiences, or out of school in community-based informal projects. Mentors such as teachers and community organizers play a key role in these opportunity structures, helping youth who might not otherwise be involved and modeling how to engage in society in appropriate and effective ways. The outcome of sociopolitical development is engagement with society. Students who develop the assets of a critical consciousness and sense of agency in positive, supportive settings may develop the habit of mind to act in civically minded ways. This model does not specify a type of citizen to be developed, but clearly a young person who is critical, empowered, and conscious will be responsible, attuned to social justice issues, and prepared to actively participate in civic life.

There are many ways that active learning and geospatial technologies can contribute to this model of sociopolitical development, including the use of interactive mapping sites like the excellent resources of the major news media; volunteered geographic information; citizen science initiatives; and using geospatial technologies to open students' minds to characteristics of their community. The key is the use of geography and geospatial thinking to encourage a sense of efficacy and to offer learners opportunities for action and a sense of agency. Briefly below I introduce three venues to create spatial citizens.

Interactive Mapping Sites: A number of prominent newspapers and media providers in the United States, Canada, and Europe, notably the Washington Post, the New York Times, and The Atlantic Magazine's CityLab, use powerful interactive maps to explore a range of spatial issues. In the hands of artful geography teachers, these resources can encourage young adults to examine significant political issues often focused on social justice and to develop knowledge, empathy, and key citizenship practices.

Voluntary Geographic Information (VGI) Initiatives: In many recent natural disasters such as earthquake relief in Nepal and Haiti, citizen cartographers have contributed their time and cartography/GIScience skills to serve humanitarian efforts using OpenStreetMap (https://hotosm.org). Disaster relief has become a shared experience with individuals thousands of miles away able to help through spatialized efforts. The focus is not only on disasters but on community development as well. The mapathon movement affiliated with a range of NGO's (https://www.missingmaps.org/about/) sets up skilled and unskilled workers to map places that

would not normally be mapped. They work closely and collaboratively with communities to help them develop the maps they want and need. In the United States there is a burgeoning movement in which classroom teachers use geospatial technologies to identify and investigate topics of their choosing. Frequently these project focus on a critically envisioning of students' neighborhoods to produce findings and present them to community leaders (Schlemper et al. 2018). Initial findings related to such projects show a greatly enhanced sense of efficacy in student participants and commitment to civic engagement.

Citizen Science Projects: The Citizen Science movement has been framed as a way to excite the general public about science and to demystify the processes of "discovery." The goals for such projects are to recruit amateurs to work with professional scientists and to model *doing* science. In many cases it is difficult to distinguish between VGI initiatives and Citizen Science projects; in both instances individuals are engaged in collecting data and sharing it using web-based services. However, Citizen Science projects tend to focus more on environmental issues and concerns. Typically, youth participate in a group endeavor designed to explore and improve their community such as by participating in an inventory of plants and animals as in a BioBlitz (https://www.inaturalist.org/pages/bioblitz+guide). It is hoped that learners develop the critical and analytical skills essential to civic engagement, particularly as it relates to environmental issues.

Spatial thinking, thus, is at the heart of both enhanced academic achievement and overall human development. It supports individual's understanding of the world in which they live, particularly in terms of comprehending the relationships among space, place, scale, power, and human-environmental interactions.

The Pathway Forward

To conclude I wish to return to three questions that I posed at the beginning of the paper: 1) how do geographic knowledge, skills, and practices develop across individuals, settings, and time and how can these understandings be used in transformative ways; 2) in what ways can geography educators, through curricula and instructional materials, contribute to creating societies that appreciate, respect, and capitalize on difference?; and 3) in what ways can geography educators help their students to become empowered to participate actively in society? Let me address each in turn.

Question 1: how do geographic knowledge, skills, and practices develop across individuals, settings, and time and how can these understandings be used in transformative ways? In this paper I addressed the first question through an examination of research on spatial thinking and spatial pedagogies. I explained the ways that spatial abilities are affected by individual differences such as gender and age, noting, however, that these differences can be mediated through formal and informal educational experiences as well as through certain types of play activities. I then explored the ways that attending to spatial thinking through explicit spatial training can help to transform society by opening access to highly spatialized fields like science and engineering to women and others often at a disadvantage in such disciplines. A second transformative value of spatial thinking is through the affordances to young people of gaining a set of skills and tools of analysis, supported by geospatial technologies, to use in shaping their spatial narratives. The concept of spatial citizenship is linked to this. Young people familiar with the practices of geography are well-armed to find their voice, to take critical views of the places they live, and to feel a sense of agency. While there are a number of projects exploring spatial citizenship, this is an area in need of further careful scholarship to expose what types of experiences work best for different groups of youth and the kinds of supporting instructional materials and curricula are most effective.

Question 2: in what ways can geography educators, through curricula and instructional materials, contribute to creating societies that appreciate, respect, and capitalize on difference? This question was addressed peripherally in the discussion on how spatially enhanced learning experiences can ameliorate individual differences related to spatial abilities. This is an area that is in need of further research by geography educators. It is one thing to recognize that gender and socioeconomic status play a role in access to certain disciplines and workplace opportunities. It is another thing to understand concrete strategies to progressively develop the knowledge and skills necessary to overcome these challenges. It is clear that some interventions are effective but these do upset the status quo. Thus, they may be controversial in some settings. The focus on spatial citizenship is another area that may benefit attempts to respect difference. Imagine the capacity of this idea to give previously marginalized young people a sense of belonging, efficacy, and power in the communities in which they live. Spatial thinking has the capability of making at least some youth more engaged in their societies.

Question 3: in what ways can geography educators help their students to become empowered to participate actively in society? The third question actually is a different way to ask about the value of a geography education and in particular, an education rich in spatial representations, critical spatial analysis, and active inquiry. By paying attention to spatial issues, spatial education, and spatial thinking geography educators can prepare their learners with the skills and habits of mind to envision the world in new ways and to work through a spatial lens to perceive and solve a range of problems. This will require a new perspective on curricula and instructional materials, a re-envisioning of the purpose of geography education, and a deep commitment to research that informs and directs these reforms. Too often geography educators are most concerned with the status of our subject in school curricula rather than the quality of the content we teach. We need to be more attentive to the ways that our discipline improves the lives of those who learn it and the societies in which we exist. A path forward for geographers appears to be through spatial thinking and spatial citizenship.

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