Chapter 24

Digital Earth Education

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Abstract Digital Earth (DE) education provides students with geospatial knowledge and skills to locate, measure, and solve geographic problems on Earth's surface. The rapid development of geospatial technology has promoted a new vision of DE to embrace data infrastructure, social networks, citizen science, and human processes on Earth. The high demand for a geospatial workforce also calls for an ever-changing, diverse form of learning experiences. Limited efforts, however, have been made regarding DE education to adapt to this changing landscape, with most interventions falling short of expectations. This chapter gives an overview of current teaching and learning structures with DE technologies. Successes and obstacles for K-12 education are explored first, followed by classroom technologies and experiential learning and outreach exercises such as academic certificates and internships in higher education. Taking the geospatial intelligence model from the U.S. Geospatial Intelligence Foundation (USGIF) as an example, recent advancements in DE education for professional careers are described via its geospatial competencies, hierarchical frameworks, and credentials. In alignment with the principles of DE development, future DE education calls for an integrated learning framework of open data, real-world context, and virtual reality for better preparedness of our students in the geospatial world.

Keywords K-12 · Higher education · Internships · Geospatial competency · Credentials

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24.1 Introduction

The vision of Digital Earth (DE), initially presented by former U. S. Vice-President Al Gore in 1998 (Gore 1999), has been to build a multi-resolution, three-dimensional representation of the planet in a system that allows users to navigate through space and time and to support decision-makers, scientists, and educators (Grossner et al. 2008; Goodchild et al. 2012). With recent technological advances, the system is now much closer to reality by utilizing vast amounts of geographic information. In the Big Data era, new visions for DE are emerging to take into account the developments in web-enabled sensors and opportunities provided by social networks and citizen-contributed information. Advances in information technology, data infrastructures and Earth observations, and the scientific and societal drivers for the next-generation of DE have been highlighted in recent literature (e.g., Craglia et al. 2012; Goodchild et al. 2012; Guo et al. 2017).

Little of the DE development focus, however, has been cast on education. The descriptor of user(s) is generically defined or refers to, at best, a few professional organizations. Nowhere in this particular vision of users does the *learner* appear even though education has caught the attention of DE proponents in the past (Kerski 2008; Donert 2015). The focus of this chapter is on the *learner* and the education/training structures that support teaching and learning with DE technologies. K-12 successes and obstacles are identified first, followed by higher education, professional credentialing opportunities, and finally the future of DE education and professional development.

24.2 Digital Earth for K-12

A variety of geospatial technologies are currently used in K-12 classrooms, and how to best do so has been pondered for some time (Fitzpatrick 1993; Nellis 1994). A keyword analysis of the *Journal of Geography*—a journal primarily dedicated to teaching and learning in geography—found first-time article keyword entries for remote sensing in 1990, computers in 1991, global positioning systems in 1993, geographic information systems in 1993, and Google Earth in 2007, indicating a steady progression of interest in these tools for education (Mitchell et al. 2015). More attention has been placed on educational uses of Geographic Information Systems (GIS) generally (Kerski 2008; Kerski et al. 2013), but concern for remote sensing (Kirman 1997), Google Earth (Patterson 2007; Zhu et al. 2016), and other virtual globe representations (Schultz et al. 2008) also is evident.

Classroom use of GIS began to appear in the 1990s (Kerski et al. 2013) and scores of research articles related to its educational use have appeared since in journals such as *International Research in Geographical and Environmental Education*, *Journal of Geography*, and *Cartography and Geographic Information Science*, among others. There are far too many sample articles to acknowledge in this short overview, but

topics have included GIS and elementary school map skills (Shin 2006), bridging GIS teaching and learning between high school and college (AP GIS&T Study Group 2018), and GIS teacher training (Hohnle et al. 2016; Hammond et al. 2018). This interest was driven in large part by the ability to harness GIS for problem-based learning and the study of real-world phenomena and concerns (Milson and Kerski 2012).

Several examples illustrate this last point. In the United States, Mitchell et al. (2008) worked with middle school students to map hurricane storm surge and a chemical spill in relation to vulnerable populations such as children and the elderly; young people in 4-H clubs created trail maps and plotted locations for industrial development (Baumann 2011); and The Geospatial Semester offered secondary students the opportunity to learn about geospatial technologies and increase their spatial vocabularies by working on local problems such as siting a solar farm (Kolvoord et al. 2019). Elsewhere, students have used the technology to design a high-speed railway loop (France), map invasive flora (Canada), and identify locations for street lights to enhance public safety (Japan) (Kerski et al. 2013).

Whether and how GIS is used in instruction varies globally. The various structures that govern education and curriculum-making are important drivers in this regard. In countries where GIS has been made a part of the national curriculum, the spread of GIS in education has been faster (Kerski et al. 2013; Rød et al. 2010; Lam et al. 2009). These countries include China, Finland, India, Norway, South Africa, Taiwan, Turkey, and the United Kingdom. Note that, save for the Americas, these locations span the globe.

These achievements aside, most advocates would be quick to admit, however, that the promise of geospatial technology use in the K-12 classroom has fallen far short of expectations (Collins and Mitchell 2019). Some of the original obstacles plaguing greater use of geospatial tools by K-12 students remain depending on location; these include the inaccessibility of computers such as in South Africa (Breetzke et al. 2011) and Turkey (Demirci 2011) and not having a teacher and/or an educational context whereby tool use is well-taught and encouraged (Mitchell et al. 2018). As previously noted, educational standards also vary considerably internationally, meaning curricular integration of the technology can be equally variable. Improvements have included a decrease in software and hardware costs and a much greater availability of data—especially local data—for use in class projects. A focus on the student necessitates an emphasis on their teachers as well. Three important aspects apply, here. First, before a teacher embraces DE technologies they should also understand *geography* as a discipline for the unique contribution a spatial perspective brings (Bednarz and Ludwig 1997; Bednarz and van de Schee 2006). Too many teachers hold a narrow and information-oriented view of geography that is limiting for instruction (Bourke and Lidstone 2015). Second, a teacher must perceive DE technologies as useful and able to create learning opportunities not afforded by other methods (Lay et al. 2013). Finally, after fostering this positive mindset, DE teacher professional development (PD) must include several key components.

In order for teacher's DE PD to be successful, to have a "stickiness" (in other words, staying power and continued classroom use), the learning experience must be

of sufficient duration. Too often geospatial training workshops are short in duration with little ongoing support (Baker et al. 2015). Successful teacher implementation requires long-term support instead of one-time PD. For example, Walshe (2017) showed that pre-service geography teachers with “*gradual yet repeated exposure to GIS with increasing complexity across the [school] year*” better developed their practice. Professional learning communities also sustain DE use. A strong cohort of learning peers can result in teachers from different disciplinary areas assisting and working with each other (Mitchell et al. 2018). Encouragement by school administration is crucial. Devoting new resources and allowing teachers to try something out of the norm: these are DE features where administrative support is necessary (Hong and Melville 2018). The best DE PD brings together diverse subject matter expertise and connects the learning to the existing curriculum to elevate the relevance of the tools to existing instruction (Hong 2014). Finally, extensive feedback and coaching, from improving classroom delivery to growing teacher confidence in using some of the more powerful features of DE tools when teaching their students, is a necessary support. Importantly, these findings are supported by work with educators across many countries, including Germany (Hohnle et al. 2016), the United States (Mitchell et al. 2018), the United Kingdom (Walshe 2017), and Hong Kong, China (Lam et al. 2009), suggesting that common teacher-training approaches in DE could be useful. A well-trained teacher corps that is mindful of how DE can be deployed in pedagogically appropriate ways (Mishra and Koehler 2006) can lead to a student population ready to connect DE technology with a problem-focused approach to learning.

24.3 Digital Earth for Higher Education

In a geospatial world, “geo” is fundamental in preparing students with geographical knowledge and skills to locate, measure, and quantify geographic phenomena (Medina and Hepner 2017). In DE higher education, students are expected to build on a firm math, science, and geography foundation with specialized courses in surveying, cartography, photogrammetry, remote sensing, and geographic information systems. The civil and governmental sectors of our society also are placing an ever-increasing reliance on the ability to build, query, analyze and communicate geospatial information to support a myriad of world issues.

24.3.1 Instructional Technologies

Pedagogical approaches for DE have developed rapidly, accompanying transformational changes such as crowdsourcing, cloud computing, and artificial intelligence (AI) that impact geospatial technologies. At many universities, introductory level GIScience courses are now taught online. Joyce et al. (2014) presented a remote

sensing computer-aided learning (RSCAL) program released in 2013 in Australia, which utilized interactive online tools to facilitate students' active learning in classrooms. As a freely available online tool, the program interacts with a range of visualization, animation, and audio to enhance learning of the fundamentals of remote sensing. Torres et al. (2017) utilized WebGIS tools to enhance personalized learning in landscape education, in which students learn the landscape as a diversity of spatial elements and a complex system of physical and human factors. Many schools also are making significant efforts to infuse their GIS curriculum with a variety of commercially available or open-source technologies such as QGIS (QGIS Development Team 2018) and geospatial course materials developed by Boundless, a geospatial technology firm.

Since the debut of geobrowsers such as Google Earth in May 2005 (Fig. 24.1), these new geospatial tools make spatial data easily available worldwide and mark an evolutionary point for the DE community (Foresman 2008; Bearman et al. 2016). An increasing number of courses have adopted geobrowsers and virtual globes for classroom use. A compilation of similar geobrowsers and virtual globes released by a variety of private and public sectors all over the world is shown in Table 24.1. These user-friendly digital platforms are visually appealing to students and present a useful device for faculty to create a virtual Earth environment for interactive learning and enhanced student spatial thinking. By interacting with the real and digital Earth and within collaborative environments, students not only use and analyse data,

Fig. 24.1 The interface of Google Earth (Earth version 7.3.2, DigitalGlobe, Inc.)

Table 24.1 A list of geobrowsers and virtual globe platforms worldwide

Name	Source	Website
Google Earth	Digital Globe, USA	https://www.google.com/earth/
OpenStreetMap	OpenStreetMap Project, USA	https://www.openstreetmap.org
WorldWind	NASA ^a , USA	https://Worldwind.arc.nasa.gov
Cesium	Analytical Graphics, USA	https://cesium.com/ion
GBDX	DigitalGlobe, USA	https://platform.digitalglobe.com/gbdx
Bing Maps	Microsoft, USA	https://www.bing.com/maps
ArcGIS Explorer	ESRI, USA	www.esri.com/software/arcgis/exploer
SkylineGlobe	Skyline Software Systems, USA	http://skylineglobe.com
Open Data Cube	Digital Earth Australia, Australia	https://www.ga.gov.au/dea/odc
Géoportail	DGME ^b , France	https://www.geoportail.gouv.fr/
Digital Earth Science Platform	Chinese Academy of Sciences, China	http://english.radi.cas.cn/ (to be released in late 2019)

^aNASA: National Aeronautics and Space Administration^bDGME: French General Directorate for State Modernisation

but contribute to its collection, processing, and integration with other freely available platforms. DE is becoming an educational tool and a medium to facilitate our improved understanding of both natural and human processes on Earth (Annoni et al. 2011; Patterson 2007). Geo-media, for example, is a recently emerging concept that links geoinformation, online mapping, mobile APPs and volunteered geographic information for multimedia representation in classroom usage (Donert 2015).

Rapidly evolving geospatial platforms, open-source programs, and citizens-as-sensors (Goodchild 2007) allow for a higher level of spatial data adaptation in classrooms. These widely available geoportals, however, have their own limitations in DE pedagogy. On the one hand, they put pressure on educators to continually update their curriculum. Gaps between classroom learning and workplace frontiers are often observed when educators cannot stay abreast of all new changes in the market. On the other hand, some argue that while students can easily access spatial data using these tools, the level of spatial literacy they gain can be reduced and their critical spatial thinking skills can be endangered (Bearman et al. 2016). Most recently, numerous geo-“hackathons” have been conducted around the globe where geo-enthusiasts capture geo-tagged information or data using a variety of tools (GPS, WPS, RFID, etc.) which is then analyzed using GIS. The hackathon concept is intended to encourage digital innovation with existing assets and resources (Briscoe and Mulligan 2015).

While hackathons provide opportunities for collaboration and field work and allow students to learn and manipulate the tools, limited timing and focused technologies may have students entirely miss the geographic context and its principles.

24.3.2 *Academic Curricula*

As presented by the United Nations Educational, Scientific and Cultural Organization (UNESCO), education fulfils its valuable role of providing foundational knowledge and skills, engaging critical thinking, and building students positive attitudes to become active participants in a world characterized by diversity and pluralism (UNESCO 2018). Within a “credentialism” concept framework built in the 1970s, academic credentials continue to be the basic requirement for any professional occupation. However, both industry and academic professionals have concerns over the ability of academia being able to keep up with rapid industry changes. Graduating students also worry that the skills and abilities gained are not job-market oriented. Efforts currently are being made by academia, industry and government departments tasked with education and training to search for the right mix of competencies from across industries rather than from discipline-specific degrees.

As a consequence, DE concepts are offered in a multi-disciplinary education infrastructure by departments that are more cross-disciplinary in nature. Educating a student as a qualified geospatial analyst requires coursework in image interpretation, geographic information systems, open-source information, geospatially referenced data representation, management, and analytical skills. In the United States, more than 50% of GIScience courses are offered in geography and environmental science departments (ASPRS 2004); offerings also appear in other academic departments such as forestry, oceanography, engineering, or even public health and political science. The applied context of DE is positioned at multiple spatial scales and is interconnected among these disciplines. In a survey of 163 GIScience education programs at U.S. institutions in 2007–2008, Kawabata et al. (2010) reported that, while geography departments were the major provider of GIScience curricula, 40% of the GIScience degrees or certificates in these institutions involved multiple disciplines and nearly 20% interacted with more than three.

Unfortunately, there is no standardized DE pedagogy. The DE curriculum has complied with the systematic body of knowledge in GIScience for the collegiate teaching community. Since the early 1990s, the National Center for Geographic Information and Analysis (NCGIA) has recommended a core curriculum for GIS (Goodchild and Kemp 1992) and remote sensing (Estes et al. 1993; Foresman and Serpi 1999). Current GIScience curriculum has three primary concentrations:

- Cartography/surveying,
- Photogrammetry/remote sensing, and
- Geographic information systems/spatial analysis.

Crossing academic boundaries, DE curriculum also is undertaken by industry geospatial players in collaboration with or independently from academia. Students now have much better access to hardware, software, course materials and data via memorandum of understanding (MOUs), grants, challenges and scholarships, and partnerships between individuals, industry, and schools. For example, Esri offers GIS access to K-12 schools throughout the world, and the United States Geospatial Intelligence Foundation (USGIF) has established agreements with Digital Globe Foundation, Boundless, and Hexagon Geospatial to offer free software, data support and high-resolution imagery for classroom usage. However, the formula for seamlessly transitioning across different DE concepts is still lacking. While those out of academia focus more on technical and industry specific skills, universities continue to hold the primary role in forming a well-rounded learner who graduates with both a liberal arts background and technical, software agnostic knowledge.

The motivation to develop DE pedagogy and curriculum originates in a variety of disciplines and is driven by various stakeholders. With increasing computing power, the focus of DE has been moving toward the automation of tasks and dynamic visualization of historic or real-time data. Making sense of data has led to a shift of geospatial analysis from maps to models (spatiotemporal analytical methods; statistical, numerical, mathematical models) running on high performance computing. These are now developed and used to understand complex adaptive systems found in the natural or built environments as well as in health, political, social or economic systems on Earth (Galvani et al. 2016). With advances in computer-processing and broadband internet, geobrowsing has brought DE to the fingertips of people worldwide (Craglia et al. 2012). All these technological advances lead to changes in the workforce and in the nature of how organizations operate and interact with each other. This in turn requires re-imagining geospatial education in an excessively digital world as a customized and customizable package that takes into account rapid shifts in technology (Kantor 2018).

But DE is more than GIScience and technological development. Critical spatial thinking is a key aspect in geography as a discipline (Whyatt et al. 2011). Goodchild (2012) proposed that DE represents the full integration of geospatial technologies into the human activities of our daily life. In this sense, two learning objectives should be amended to the skill-based GIScience curriculum above:

- Critical spatial thinking, and
- Problem solving.

Thinking spatially enables better interpretation of a digital world to reach a solution: space (where); representation (what); reasoning (why); and analytics (how). Uttal and Cohen (2012) explored the relationship between spatial thinking and students' performance and attainment in science, technology, engineering and mathematics (STEM) disciplines. Similarly, it is integral to everyday life and fundamental to DE education. Without critical spatial thinking, students often ignore the context setting of spatial problems when using GIS and remote sensing software (Bearman et al. 2016). They may know very well how to run the models, but they also could have a difficult time understanding the extracted geo-information and therefore lack

the ability to truly answer the complex spatial problems facing our world today. Unfortunately, many universities still organize their GIScience courses based on the transmission of knowledge rather than on questioning and problem solving (Cachinho 2006). With skills-based lectures and lab settings, the involvement of student's critical thinking in current GIScience curricula has been limited. As outlined in Bearman et al. (2016), DE educators can teach students to understand spatial issues in three aspects: spatial data, spatial processing, and spatial outputs and communication. This systematic set of training eventually links to a positive attitude of problem solving.

The challenge of developing DE curricula within such a rapidly changing technological environment has created the need to develop curriculum frameworks made of standards, guidelines, and building blocks that can be shared and transferred across educational providers, namely universities or private or government training agencies tasked with workforce development (Malhotra et al. 2018). Reasonably, DE education is restructuring from a skills-based to a competency-oriented model to meet the rapid evolution of societal and workforce needs (Schulze et al. 2013). Reflecting a variety of competencies, a number of geographic information science and technology (GIS&T) bodies of knowledge (BoK) have been identified to guide GIScience curricular development. For example, the University Consortium for Geographic Information Science Body of Knowledge (UCGIS BoK) has been adopted by the American Association of Geographers as a set of standards of GIScience learning (DiBiase et al. 2006). DE education could follow a similar curriculum framework from essentials to advanced functions. Its breadth of knowledge equips students with geospatial and problem-solving skills to assist human activities in our society (Kantor 2018).

Even with these frameworks, challenges still remain in preparing qualified personnel for both today and tomorrow. To leverage them, external activities for experiential learning such as internships have become common in academic and professional development. These activities are crucial in shaping a student's career pathway and their implementation should start as early as high school.

24.3.3 Experiential Learning: Academic Certificates and Internships

While academic degrees are still recognized as valuable for geospatial careers, the complexity of the digital world, the fast-paced workforce environment, and continuous technology innovation have all led to a focus on competencies. Good course performance toward academic degrees, however, may not directly fulfil specific workforce needs, especially in the Big Data era with rapid technological change (Kantor et al. 2018). By the time the technologies are taught, there is little time left for critical thinking, problem solving, and integration. Academic certificates and internships are then adapted to prepare students for their geospatial careers. By interacting with

targeted communities, experiential learning activities enhance community engagement and foster critical spatial thinking of students in exploring cultural and political issues (Sinha et al. 2017). This, then, meets the ultimate goal of problem solving in DE development.

Academic certificates

Academic certificate programs are usually a series of courses provided by an educational institution. The certificate is granted as a proof that the coursework is taken and completed in a satisfactory manner. GIScience certificates, for example, have been offered as a suite of courses (12–21 credit hours) at numerous universities. The course sequence matches the learning outcomes of the geospatial curriculum framework.

The USGIF Geospatial Intelligence Certificate Program is an excellent example of academic certificates in the scope of DE. Currently there are seventeen USGIF accredited institutions in the United States and Europe offering a geospatial intelligence certificate or degree. Their course curricula bridge classroom learning and professional training and offer future decision-makers actionable insights about Earth and its people for business, humanitarian, security, and defense-related decisions. In general, current geospatial intelligence certificate/degree programs address three overarching educational objectives:

- to provide traditional students with a broad base of the knowledge, skills, and abilities requisite to work in the geospatial industry at an analyst level or higher;
- to offer a means of educating the non-traditional workforce by balancing work-related training provided in formal collegiate education; and
- to leverage education, training, and work experiences to obtain industry recognized credentials (certification and licensure).

Aside from technical and discipline-specific applied courses, all students seeking the geospatial intelligence certificate or degree also are required to complete a capstone project/experience. As an example, the following outlines the capstone requirements at Delta State University (Mississippi, USA), the first institution to offer an undergraduate geospatial intelligence degree:

- Applied projects: The program of work must demonstrate the use of geospatial technologies to improve workflow efficiencies, consequence analysis, new applications or methods, or improve return on investment.
- Applied geography: The program of work associated with an applied geography project must focus on improving the understanding of a geographic region through the use of geospatial technologies.
- Geospatial education: The program of work must demonstrate a need for the creation of educational materials pertaining to a common challenge encountered when using geospatial technologies.

Academic certificate programs have been in effect in various countries. A good example of international efforts is UNIGIS Distance Learning, a worldwide network of universities from nine countries and regions including Austria, Portugal, Spain, Hungary, Poland, Netherlands, United Kingdom, Latin America, and the United

States (<https://unigis.net/>). Initiated in 1990, UNIGIS offers professional diplomas, postgraduate certificates, and master's degree programs in six languages within its global network of fifteen Study Centers. All of these programs are in the fields of GIS, Geoinformatics, geospatial intelligence, and geospatial leadership.

Internship Programs

Traditional learning theories in academic curricula educate students for critical thinking, but often lack hands-on training to prepare them for authentic career work. To fill in this gap, many institutions have established internship programs to build a flexible learning environment for students to meet the rapidly evolving geospatial landscape. For example, the University of South Carolina (South Carolina, USA) offers an internship course—GEOG 595 (Internships in Geography)—as an experiential study for geography majors and minors. Through a semester-long internship contract with community partners, this 3- to 6-credit course prepares students for the workplace and give students an opportunity to explore career options and to put their skills into practice. For students in DE education, their internships engage with private and public partners in the geospatial community to support personalized learning. To establish a common ground for the program, it is crucial to build a community network across competencies that share mutual interests in geospatial analysis. The network comprises geospatial agencies and industries at local, state, regional, and national levels to support interns with activities that vary in terms of skill requirements and learning objectives.

The internship programs utilize a personalized curriculum and education metric. The evaluation of an intern's learning is job-specific. Given the diversity of internship activities for different interns, the learning outcomes cannot be quantified using traditional assessment schemes such as quizzes, homework, and exams. Kantor et al. (2018) propose discipline-based education research (DBER) in geospatial intelligence to better educate students to think about and understand their location-based tasks and to reflect back with improved outputs (Colom et al. 2010). The DBER strategy can be embedded in the internship courses. With job tasks and learning outcomes outlined in each internship contract, the intern perceives, understands, and embraces the critical connections between geospatial competencies and the degree-offering discipline. In this way, the curriculum is specifically designed to fit different student learning styles (Dolan et al. 2017).

The personalized curriculum adaptively helps an intern gain human intelligence on problem solving by observing, measuring, assessing and reporting the problems, and improving the individual abilities needed to cope with challenging situations. Human intelligence points to the fundamental difference between humans and machines when programming has reached its limits and run out of data (Hawkins and Blakeslee 2005). This type of adaptive learning (Posner 2017) is fundamental in DE curriculum development, but has been a major drawback in traditional unified curricula in classrooms.

Aside from the regular, full-time students in experiential learning, there is a growing student population formed of adult learners seeking to complete their degrees or to earn academic certificates. Many of these students return to school with work experience within the field and are looking to gain recognized credentials that would

help them advance their careers. Among various skills programs, one good example is the Postgraduate Training Program operated by the Center for Spatial Data Infrastructures and Land Administration (CSDILA) at the University of Melbourne (Melbourne, Australia). The Center attracts world class postgraduates to gain specialized supervisory expertise in spatial data infrastructure. These students are motivated and informed (with experience), expect to apply newly gained knowledge and skills the next day, and thus create a different type of pressure on collegiate curricula. “Experience” is now expressed in various forms, carries a multitude of names (i.e. internship, apprenticeship, experiential learning, field-based training, and working knowledge), and has become part of the collegiate educational journey.

24.4 Digital Earth Education to Professional Careers

The rapid development of geospatial technology enables considerable employment growth in the geospatial technology industry as well as DE-related service employment sectors and fields. Geospatial technology has been identified as one of the three (along with nanotechnology and biotechnology) most important emerging and evolving fields with the highest number of new jobs (Gewin 2004). The U.S. Department of Labor reported an annual growth of 35% in the geospatial workforce (USDOL 2005). Upon a worldwide study by Oxera (commissioned by Google), the global geospatial services sector generated \$150–270 billion per year (NSDI 2013). Various efforts, from academia to workforce, have been made to maximally prepare students for the ever-evolving geospatial world. For example, the Spatial Industry Business Association (SIBA), an association in Australia and New Zealand, has established an educational initiative, Geospatialscience, to build an interactive network that bridges school-age students with DE-related careers in the geospatial industry.

This section presents an example of DE education to professional careers in the field of geospatial intelligence, which has developed competencies to better complement DE by illustrating its real-world application. The geospatial intelligence model can serve as a catalyst for making the DE vision a reality via tools, expertise, and techniques, and integrate them into a new interconnected platform. Geospatial intelligence can bring these tools and perspectives forward to help extract actionable information from vast amounts of geographic data. Closely related to this chapter’s topic, geospatial intelligence already has a framework for teaching and learning that could leverage DE education.

24.4.1 Geospatial Competency-Based Models

As early as 1999, Lucia and Lepsinger (1999) offered this definition of a competency: “... a cluster of related knowledge, skills, and attitudes that affects a major part of one’s job (a role or responsibility), that correlates with performance on the job, that

can be measured against well-accepted standards, and that can be improved via training and development.” This definition leads to a formula where competencies (C) are proper subsets of well-accepted industry standards (IS), training (T), and performance on the job (PJ):

$$C \subset IS + T + PJ \quad (24.1)$$

This is a formula for training, but competencies also are becoming a major focus in education. Competency-based education provides the foundational knowledge, skills, and, most importantly, attitudes towards a profession. The purpose of “education” is to ensure the attainment of these specified knowledge, skills, and “attitudes” (Banathy 1968). Attitudes in particular are very volatile competencies and depend on external influences and self-motivation. They also are very difficult to assess and thus improve. In education, the previous formula would look different as it would need to incorporate these attitudes as essential in teaching students why to use the system and how to improve it (at the graduate level), not just how to build and operate it (technical training). Thus, the education formula is where competencies (C) are proper subsets of well-accepted (industry) standards (IS), education (E), and apprenticeship (A):

$$C \subset IS + E + A \quad (24.2)$$

Both education and apprenticeship help build not only knowledge and skills, but also attitudes designed and assessed according to industry standards. With changing demographics in student populations (e.g., an increase in adult learners), as well as changes in the modes of delivering educational and training content, attitudes are becoming an important competency to consider in both education and training.

24.4.2 Geospatial Frameworks

Looking back at the geospatial credentials market, despite all the societal advances in technology and connectivity, the 1999 view on competency-based training remains unchanged while education continues to grow more interconnected with industry standards. The major shifts in both have been witnessed by industry standards and attitudes which in turn have impacted knowledge and skills or abilities expected from the workforce. In building the geospatial workforce, several organizations have been using collaborative and cross-industry efforts to identify job specific competencies that are then followed by developing geospatial frameworks for competency-based collegiate (4 year and vocational) and training offerings.

Two prominent frameworks are the Geospatial Technology Competency Model (GTCM) designed by the National Geospatial Technology Center of Excellence (GeoTech Center) and the Geospatial Intelligence Essential Body of Knowledge (EBK) designed by USGIF. Both competency-based models have been developed

with help from subject matter experts (SMEs) from across industry, government, and academia. The results should reflect the competencies needed by today's geospatial professionals and guide both educational and training curriculum development.

The GTCM was submitted to the U. S. Department of Labor (USDOL) in August 2018 and a working version was released in September 2018 (GeoTech Center 2018). The GTCM has become an important resource for defining the geospatial industry and a valuable tool for educators within the domain of geospatial technology. The University of Southern Mississippi's Geospatial Workforce Development Center conducted an initial effort in the early 2000s to define skills and competencies, an effort that led to the first draft of the GTCM. Work continued under the direction of the Geographic Information and Technology Association (GITA), the American Association of Geographers (AAG), and the Wharton School of Business at the University of Pennsylvania (DiBiase et al. 2006) but it remained a draft. In early 2009 the GeoTech Center became involved in the effort to complete the GTCM. A broad-based panel of geospatial experts were convened and suggested including two industry-related technical competencies: industry-wide and industry-specific, in the model. Public comments were sought, and comments were addressed with a final GTCM draft submitted to the U. S. Department of Labor's Employment and Training Administration's (DOLETA) Geospatial Technology Competency Model. The draft was approved by DOLETA in 2010. The industry has continued to evolve and grow and the GeoTech Center has undertaken the work to update the 2010 version of the GTCM. Partnering with DOLETA, the GeoTech Center updated the GTCM in 2014. The USDOL prefers that competency models are updated every four (4) years (GeoTech Center 2018). The 2018 GTCM update focuses on Tiers 1–5 as defined below:

- Industry-Related Technical Competencies:
 - Tier 5—Industry-Specific Technical Competencies
 - Tier 4—Industry-Wide Technical Competencies
- Foundational Competencies
 - Tier 3—Workplace Competencies
 - Tier 2—Academic Competencies
 - Tier 1—Personal Effectiveness

USGIF produced the Geospatial Intelligence EBK by conducting a cross-industry job analysis to identify the knowledge, skills, and abilities critical to the geospatial intelligence workforce in consultation with psychometric consultants and the geospatial intelligence community. Qualified Subject Matter Experts (SMEs) from government, industry, and academia participated in each phase of the job/practice analysis to ensure an accurate reflection of geospatial intelligence practices. The Geospatial Intelligence EBK was revised in 2018 and published in 2019 with major additions and improvements. The GEOINT EBK describes geospatial intelligence competency and practice in terms of key job tasks and essential knowledge, skills, and abilities required for a professional to be successful. These are organized into four competency areas as described below.

- Competency I: GIS & Analysis Tools describes the knowledge necessary to ensure the various elements and approaches of GIS and analysis are properly understood in order to successfully capture, store, manage, and visualize data that is linked directly to a location.
- Competency II: Remote Sensing & Imagery Analysis describes the knowledge necessary to generate products and/or presentations of any natural or human-made feature or related object of activity through satellites, airborne platforms, unmanned aerial vehicles, terrestrially based sensors, or other similar means. This competency area contains the knowledge necessary to synthesize technical, geographic, and intelligence information derived through the interpretation or analysis of imagery and collateral materials as well as the processes, uses, interpretations, and manipulations of imagery for dissemination.
- Competency III: Geospatial Data Management describes the knowledge required to acquire, manage, retrieve, and disseminate data to facilitate integration, analysis, and synthesis of geospatial information.
- Competency IV: Data Visualization describes the use of cartographic and visualization principles to generate products that represent information about the physical environment that can be easily understood by decision-makers.

The Geospatial Intelligence EBK also includes cross-functional knowledge areas. These are necessary when there are widely accepted knowledge, skills, and abilities that transcend specific core competencies or where competencies are found across the full scope of practice. Cross-functional geospatial intelligence knowledge, skills, and abilities generally reflect:

- Qualitative “soft skills” used in geospatial intelligence,
- Unique aspects of the universal geospatial intelligence tradecraft applicable to the majority of practitioners and,
- Common geospatial intelligence knowledge and practices that, if followed, will improve the performance of a practitioner (USGIF 2018).

The Geospatial Intelligence EBK was initially developed for working professionals, not geared towards an academic curriculum. With the growth in the number of academic institutions offering geospatial intelligence credentials (certificates and, more recently, degrees), the EBK needed to be restructured for its broader audience. To make it more “academic friendly”, USGIF has invested in recent updates of the Geospatial Intelligence EBK to include learning objectives at four different experience levels and designed with regards to Bloom’s Taxonomy levels and psychometrics. Faculty will now be able to devise and maintain a master course map with formative and summative learning objectives as well as improve teaching and learning assessments. Assessment data, captured by faculty, will be used to evaluate student success with respect to each competency at the end of each semester. The academic certificates are expected to provide a basal measure of competency across the full spectrum of the Geospatial Intelligence EBK topics aimed at an “Essentials” exam (already piloted during Spring of 2019) level that will allow students who pass the exam to enter the professional world and gain an entry-level certification.

A geospatial intelligence degree is expected to provide the knowledge and skills required at the Certified GEOINT Professional (CGP) exam level. Institutionally designed frameworks for assessing student mastery is expected to be incorporated into their existent learning management systems (i.e. Blackboard, Moodle, Canvas) and the resulting data will be used to guide self-improvement. Student success rates with credentialing exams taken post-graduation and job placement also could serve as a secondary means of assessing program effectiveness. The 2018–2019 revision and updating of the Geospatial Intelligence EBK started from a “matrix” tool that was developed for each competency in the current EBK, followed by the identification of Emerging Geospatial Intelligence Competencies. Each matrix includes competency specific topic areas in the left column, as well as questions pertaining to each proficiency level (i.e., Prerequisites, Foundation, Application, Mastery/UGP) in the subsequent columns. The questions read as:

- Question 1: What do you need to know to be ready to learn about the Topic Area at a fundamental level?
- Question 2: What do you need to learn about the Topic Area at the fundamental level?
- Question 3: What do you need to know to apply the Topic Area?
- Question 4: What do you need to know to advance fundamental knowledge in the Topic Area?

The SMEs were then assigned a specific matrix to author, and added content indicating the knowledge and skills necessary to adequately address each topic area at the specified proficiency levels. Then, learning objectives for each matrix subtopic (i.e., knowledge and skills) were generated by the SMEs (Table 24.2).

Therefore, the new EBK features the following:

- Vetted learning objectives for each subtopic identified during the “deep dive” process.
- A numbering scheme for the EBK to facilitate easy communication and identification of learning objectives.
- A progression of subtopic knowledge necessary to grow and advance within a given competency.

The new EBK format is significantly more academic curriculum friendly and helps guide the pathway into geospatial intelligence learning starting from high school, moving into college, and then into the professional workforce. In addition, the newly updated Geospatial Intelligence EBK has identified and recognized the importance of a number of emerging areas, namely: Data Science, Use of varied datasets, Machine Learning, Virtual reality, Neural networks/AI, small Unmanned Aerial Systems (sUAS), Automation, and Critical thinking. Therefore, geospatial intelligence has both human and technical scopes. People are essentially trained to utilize various technical tools to understand human geospatial behaviour.

Today, the geospatial intelligence academic programs initially built upon the GTCM are shifting their curriculum towards the Geospatial Intelligence EBK to better reflect the program’s growth, maturity, and establishment as a standalone

Table 24.2 An example competency area (prerequisites) of remote sensing and imagery

Matrix subtopic	Learning objective(s)
Basic computer literacy	Execute basic computer tasks including typing, use of commercial software products, navigating file systems, reading and writing computer files, internet navigation, downloading and uploading files
Basic digital image processing	Summarize the steps taken to perform basic digital image processing Explain why digital image processing is performed
Remote sensing software package	List the common remote sensing software packages and their uses
Basic remote sensing process and components	Outline the basic remote sensing processes List the components that coincide with each remote sensing process
High school physics	Integrate high school physics principles (e.g., the electromagnetic spectrum, principles of light and optics, statics and kinetics etc.) with other areas of study (e.g., math, other science)
High school math (algebra, geometry, trigonometry, and statistics)	Explain how advanced math principles (e.g., algebra, trigonometry, geometry, and statistics) apply to other fields, such as science

geospatial discipline. Efforts are being made and there is a strong ongoing partnership between the GeoTech Center and USGIF to leverage the use and fusing of both frameworks for the benefit of the greater geospatial community. These frameworks are being updated so that all the programs of study can maintain currency and relevance to the discipline. To provide a balance of theory, technical skills development, and ethical reflection, the presentation of knowledge required to achieve professional competency would be sequential and interlocking. Programs of study should aim to first orient students to fundamentals before embarking on specialization, whereas specialization should serve as a means of broadening knowledge rather than limiting practice.

In addition to the GTCM and Geospatial Intelligence EBK, the National Science Foundation also has supported various projects aimed at the development of job/occupation specific Developing a Curriculum (DACUM) frameworks (e.g., GeoTech Center produced a DACUM for GIS & Remote Sensing, Northland Community College DACUM for the sUAS maintenance technician, etc.). These newly updated competency models demonstrate a movement towards making them more “education friendly” via the introduction of learning objectives and outcomes as well as a separation into levels of expertise based on Bloom’s Taxonomy. This again demonstrates the need for a continuum between education and training in building career pathways.

24.4.3 Geospatial Credentials: Certificate Versus Certification

Despite significant efforts towards establishing, maintaining, and updating the competency models in the geospatial community, the geospatial credentialing market use of the terms certificate and certification is confusing. There is ambiguity over the terms as well as the credit value between course-based academic certificates offered by numerous universities and those certificates and certification obtained after attending an hour, a half-day, a full-day, or several days/weeks/months of training in person or online.

The Cambridge Dictionary defines certification as “*a proof or document providing that someone is qualified for a particular job, or that something is of good quality*”. It then goes further to imply that, for example, more adult workers are going back to school for a certification to improve their job opportunities. Based on the current credentialing market, the rule of thumb is that certifications are geared towards to-be-certified professionals; that individuals are at least at the journeyman level with a balanced combination of educational credentials and hands-on, practical work experience; and that the credential needs to be maintained through Continuing Education of Professional Development Units. One exception is Esri’s Technical certification that does not require maintenance because it is largely focused on Esri’s software as opposed to the software agnostic certifications offered by the aforementioned professional organizations.

In comparison, an academic certificate does not require maintenance once students complete the required courses. Therefore, certifications and certificates can be divided into three different major categories, all functioning under a larger “credentials” umbrella (Fig. 24.2).

The American Society for Photogrammetry and Remote Sensing (ASPRS), the GIS Certification Institute (GISCI), the National Geospatial Intelligence Agency (NGA) GEOINT Professional Certification (GPC), and the USGIF Certified

Fig. 24.2 Geospatial credentials

GEOINT Professional (CGP) and Universal GEOINT Professional (UGP) are major players in the professional geospatial certification arena (Fig. 24.2). These groups are making significant efforts to maintain software agnostic credentials. These credentials can be earned by documenting relevant educational achievements, professional experience, contributions to the profession, and by affirming a commitment to ethical practices.

In brief, ASPRS is a scientific association serving thousands of professional members around the world with the mission “to advance knowledge and improve understanding of mapping sciences to promote the responsible applications of photogrammetry, remote sensing, geographic information systems (GIS) and supporting technologies” (ASPRS 2004). ASPRS offers ten certifications (Table 24.3) geared towards photogrammetrists, mapping scientists, and technologists. GISCI is a non-profit organization that provides the GIS community with a certification program leading to GISP® (Certified GIS Professional). NGA offers the government a focused GEOINT Professional Certification (GPC) program as part of a broader Under Secretary of Defense for Intelligence (USD(I)) initiative to further professionalize the Department of Defense Intelligence Enterprise (DIE) workforce (NGA 2018).

USGIF is a more recent addition to the professional certification community, but the only one to offer a sequence of geospatial intelligence credentials that range from rigorously evaluated academic curricula via USGIF accreditation of certificates and degrees to the offering of an Essentials (entry-level) exam and professional certifications. The USGIF accredited programs offer certificates that require at least 18 (undergraduate) or 12 (graduate) credits of coursework, including a capstone project resulting from research, internship, or apprenticeship work. The value of these certificates is considered superior to that of other “certificate” credentials given the depth and breadth of required curricula. With the spring 2019 planned introduction of its Essentials exam and its ongoing K-12 curricula development efforts, USGIF intends to bridge the gap between high school prerequisites, collegiate credentials, and professional certifications in a continuum of building blocks based on the Geospatial Intelligence EBK (USGIF 2018).

The Open Geospatial Consortium (OGC) “*provides a consensus process that communities of interest use to solve problems related to the creation, communication and use of spatial information*” through the OGC Standards Program and, lately, its own certification and training (Open Geospatial Consortium 2018). OGC’s standards are used by its community of interest which includes those in aviation (air travel safety and operational efficiency), built environment and 3D (open standards to support productivity across the supply chains of the building design, physical infrastructure, capital project and facilities management industries), energy and utilities, emergency response and disaster management, business intelligence, and defense and intelligence. In academia, OGC provides a fertile environment in which university geomatics, computer science, geography, and geoscience departments can modernize and advance their curricula.

Table 24.3 Examples of professional certifications

Specification	Professional certifications	Technical certifications
GIS (and Spatial Analysis)	ASPRS (Photogrammetrist, Mapping Scientist-Remote Sensing, Mapping Scientist-GIS/LIS, Lidar, UAS)	ASPRS (Photogrammetric Technologist, Remote Sensing Technologist, GIS/LIS Technologist, Lidar Technologist, UAS Technologist)
Geospatial Technology	URISA/GIS Certification Institute-Certified GIS Professional (GISP)	ESRI Technical Certification
Geospatial Science	NGA-GEOINT Professional Certification (GPC)	ORACLE Spatial Essentials
Geospatial Intelligence	USGS—Digital Aerial Certification	Microsoft technical certifications
Remote Sensing	USGIF Certified GEOINT Professional—GIS & Analysis Tools (CGP-G), Remote Sensing & Imagery Analysis (CGP-R), Geospatial Data Management (CGP-D) and Universal GEOINT Professional (UGP) designation	
UAV, UAS (Unmanned Aircraft Systems Maintenance Technician	Federal Aviation Administration (FAA)—Unmanned Aircraft Systems certification	
Web (CSW), Geopackage, Geography Markup Language, KML, Sensor Observation Service, Simple Feature Access, Web Coverage, Web Feature and Web Map Service	Open Geospatial Consortium (OGC)	
Other	Mississippi Enterprise for Technology (MsET)- SPACE and STARS Certifications	

As evidenced in this section, there have been significant advances in the geospatial educational and professional communities. Most organizations agree that competencies are best learned by following updated frameworks that are in line with industry standards as well as through experiential educational practices which include practicum, cooperative learning, internships, and that have no cost limitations. The geospatial intelligence community has achieved significant partnerships and shared

credentialing but is still working to achieve full collaboration. A shared understanding of the end value is needed to reduce the uncertainty of value and disruption in academia.

24.4.4 Geospatial Intelligence Bridging Academic and Professional Connections

The rapidly evolving geospatial intelligence field demands that academic education and professional training complement each other. The community educates students in critical spatial thinking and the conceptual use of technology to solve unstructured problems, while training focuses on increased performance in described circumstances (Kantor et al. 2018). The critical balance of academic education and practical skills training, which is necessitated throughout a geospatial intelligence professional's career, is illustrated by the age-old adages of individuals "*being educated but poorly trained*" or "*well-trained and poorly educated*" (Burrus 2016).

The core of geospatial intelligence includes providing geospatial insights to decisionmakers about human needs and potentially addressing the impact of false geospatial information that arises in a competitive environment. As a meta-discipline, it entails a view of professional know-how unbounded by typical academic and organizational limits and barriers. This is to say, geospatial intelligence is not simply a collaboration of fields, but rather a fundamental merging of disciplines in theoretical and practical ways. This implies that for one to legitimately be an expert in geospatial intelligence and DE, the individual must have know-how in many traditional domains including the technical, the human, and the problem's domain.

Geospatial intelligence also is polymorphic which explains the discipline's definitional challenge. This elusive explanation is similar to that described in the Indian parable of the blind men trying unsuccessfully to identify an elephant by touching just one of its different parts. As the poet Godfrey Saxe (1816–1997) wrote, "...*, each was partly in the right, they all were in the wrong*" (Saxe 1963).

Geospatial intelligence is a sub-discipline of geography being offered in forms of certificates and academic degrees at universities in the United States and Europe and is also cross-disciplinary in nature. It is still evolving. Moving beyond defense-related issues, the field now is leading the integration of concepts and practices in oil and gas, health, business, precision agriculture, and emergency response to name a few. It benefits engineers who build and improve weather satellites, scientists who gather measurements of atmospheric, terrestrial, and oceanic conditions, database managers, Big Data analysts, business analysts who conduct cost and marketing analyses, political scientists involved in national and international conflict resolution, law enforcement in their efforts to not only reduce but mitigate crime, and even farmers seeking the best options to increase their yields.

While some are still hesitant to embrace geospatial intelligence because of its historic association with the U. S. intelligence community, there is growing understanding that geospatial intelligence, like DE, brings a unified geospatial approach to addressing the human and environmental challenges of today and tomorrow. It has been practiced by many nations although often different terminology is used. Research on the United Kingdom and Russia highlights the lesson that success in geospatial intelligence is the combination of the utilitarian aspects of technology mixed with a sophisticated understanding of the mental maps of our self, our partners, and our rivals (Bacastow 2019). Geospatial intelligence's evolution offers a model of how DE could leverage education and training to advance the perspective where politics and culture are resistant. Geospatial intelligence's experience offers DE an example of how a cohesive curriculum can advance and help to define value.

24.5 The Future of Digital Earth Education

Based upon a decade of dialogue hosted by the ISDE, three Pivotal Principles have been identified to guide DE development in the 21st Century: open data, real-world context, and informed visualization for decision support (Desha et al. 2017). These principles call for higher accessibility and a broader, interdisciplinary context of Big Earth Data and advanced analytical visualization skills for sustainable governance and decision making. This is necessary for building an overarching framework for future DE education from K-12 to professional careers.

24.5.1 *DE Future in K-12*

DE technologies show great promise and growth potential in K-12 education, however, a number of impediments remain. Some obstacles are technical while others are institutional. As technology penetrates classrooms more readily as infrastructure and hardware costs decrease (more so in developed rather than less developed countries), it is the latter problem—institutional—that requires greater intervention. Focusing on improving pre-service teacher training programs to include more geography and DE technologies can encourage greater use and application. This will need to be followed with intensive feedback and coaching with established teachers. Research has shown that these concerns appear across the globe (Germany, Hong Kong, United States, United Kingdom, elsewhere); time and monetary resources will need to be put in place to effect substantive change. A second necessity will be to include DE technologies within academic standards. These agreed upon learning objectives drive curriculum, and if DE is specifically included then usage will rise. A number of countries have successfully done so already, but these are countries with centralized national curricula. Countries with decentralized education systems will likely remain fragmented in their K-12 DE development. In sum, K-12 DE use currently remains

scattershot and spatially variable. Although exciting projects appear in a few special cases, large-scale implementation has been elusive, and DE's K-12 potential remains untapped.

24.5.2 *Micro-credentials*

Credentials, in the form known by us today, may be very different in the future. Customization may include different time frames and delivery formats, as well as learning content that is narrower and focused on specific technologies and competencies, and delivered via transportable and transparent credentials and by traditional (universities) and/or less traditional (industry) institutions. Ultimately, all credentials should serve a larger purpose—that of building a networked human society ready to tackle the environmental, social, and economic challenges that lie ahead.

To address the rapid changes in technology and workforce competency needs, the future seems to favor a combination of credentials, from the micro-credentials enhanced by digital badges to degrees and certificates. More recent on the credentialing market, a micro-credential is a digital currency that recognizes competency in a specific task, knowledge, or skill and that the individual can use and share across various outlets (e.g., LinkedIn, Facebook) to enhance their marketability and give them a competitive edge (e.g. it can be combined with digital badges). Created as self-paced, shorter modules, micro-credentials can be more easily designed to mirror changing market trends. Also, they can be more affordable and easily digested by potential students, especially by the adult learners. Micro-credential requirements vary significantly from credential to credential since anyone can grant them and there are no official requirements.

Typically, micro-credentials are shorter than other credential options like college degrees or certificate programs; however, that is not always the case since the requirements are usually determined by the credential-granting institution. Because of the lack of consensus in terms of format and definition of what micro-credentials should entail, the reputation of the institution offering them still plays a major role in one's decision to pursue these credentials.

If carefully designed and implemented, they represent creative ways to bridge the gap between traditional higher education and 21st century technology and beyond. However, while designed for a specific purpose, micro-credentials should be thought of and planned in sequences and represent milestones in one's educational pathway (e.g. used toward a certificate and/or degree) and professional development. The existent geospatial models should be used as frameworks in the design of DE credentials to reflect annual changes and create a common language across the geospatial community.

24.5.3 Challenges and Opportunities for DE Education and Professional Development

Today, it is not surprising that DE-related credentials support the acquisition, understanding, management, analysis, visualization and (to some extent) ethics of data. According to Grossner and Clarke (2007), the term DE has come to represent a global technological initiative, but also “an intellectual movement.” While the human aspects of DE were articulated by Foresman (2008), the current DE focus is still on the technical issues of the problem without much regard to its human aspects. The vision of DE should not be solely about space and spatial relations but also about place, culture and identity, spanning the entire physical and virtual space (Craglia et al. 2012). This new vision is still only slowly being adopted and there is uncertainty related to the needed competencies required in the preparation of future DE specialists. The future of DE should be planned on several important pillars:

- Education: provides a liberal arts background, methodologies, and depth as well as breadth of thinking. The human is ultimately where knowledge work is done and those insights are produced in geospatial intelligence. It is dependent on the geospatial analyst’s meta-knowledge.
- Training/Professional development: built on education and expanding the knowledge base for increased performance. The training and professional development should focus on the human-machine team where there is a focused effort to develop information about relationships among disparate objects and events.

DE education and professional development can be implemented in several subsets as below:

- Competencies: industry-based but also focused on improving attitudes towards the discipline and the understanding of its larger, community implications.
- Technology: seen as a needed but also ubiquitous tool where abilities improve with experience and require flexibility to adjust to rapid changes;
- Leadership: the capacity to have a balanced combination of education and training/professional development to gain a holistic understanding of the problem beyond technology, combined with vision, a positive attitude, and strategic thinking.
- Research: the capacity to have a higher level of education and training/professional development coupled with imagination, creativity and positive attitudes to further contribute to the advancement of geospatial theory and knowledge as well as new improved technologies and innovative ideas.
- Education research: discipline-based education research (DBER) focused on better understanding the science of teaching and learning within and across geospatial disciplines and with sufficient resources to contribute to improved pedagogy and andragogy.

These subsets can fit under both education and training/professional development in various forms and shapes. While there is a classic continuum of education moving into training/professional development, the future movement may not be linear,

but circular in nature. Certificates, certifications, and micro-credentials can be customized to fit individual pathways at different times in one's career. High levels of flexibility, creativity, positive attitudes, and time-relevant education research and implementation will be vital in a society rapidly embracing the Digital Earth. We have been deeply transformed by a (geo)digital revolution, reaching a moment where technology is becoming a commodity more so than a skill. The future will (hopefully) bring us back to what makes us intelligent creatures on Earth, ones capable of innovation, creativity, imagination, and ethical conduct.

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