CAPACITY DEVELOPMENT IN GEOSPATIAL TECHNOLOGY - AN OVERVIEW

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KEY WORDS: Geospatial technologies, Competency, Body of Knowledge, Coordinated Capacity Development, Gender diversity.

ABSTRACT:

This article gives an overview of capacity development (CD) elements for fast-growing geospatial technologies and their applications (GSTA). While the Earth observation data and spatial analytics software tools are getting more open and accessible, lack of skilled workforce and institutional capacities are limiting effective applications. A systematic process is essential in realising required capacity at individual and institutional levels, in maintaining and upgrading technological infrastructures, and in updating geospatial data and strengthening human resources for sustainable supply of workforce. This article discusses on different user sectors and their competencies that are expected to meet their demands. It is also important to take stock of different modes of CD along with a variety of methods to select the appropriate suitable for the different users' groups for efficient knowledge transfer. In addition, this article describes briefly on two methods of building curriculum design of courses based on two different body of knowledge objectives. The importance of coordinated effort in CD programs is stressed for promoting GSTA for national and international flagship development programs such as the 2030 global sustainable development agenda. It briefly discusses on the issue of gender diversity and points out ways to increase the women participation in GSTA CD programs.

1. INTRODUCTION

Tremendous growth observed in utilising the tools of Geospatial technology and applications (GSTA) in day-to-day business of governance from national to regional, from state and to panchayat levels, has drawn a wider attention of user communities across various disciplines. While this has opened the door wide for employment opportunities in a variety of scientific and commercial applications, the job demands, yet unfortunately, outweigh the supply of a qualified workforce (Estaville, 2012). Realising the importance of workforce for devising innovative capacity building strategies, the UN- COPUOS included the implementation of UNISPACE+50 to increase the geospatial activities in global governance under its Thematic Priority 7 as Capacity building for the 21st Century (UNOOSA, 2017). Also, the Earth observation (EO) data and GSTA are getting more open and freely accessible; lack of skilled human resources and institutional capacities are limiting effective use of rich data available (Thapa et al., 2019).

All these have a disruptive impact on educational institutions and organisations to come up with appropriate capacity development programs for different workforce levels on training and education. Expertise in disciplines, covering from conventional data processing, surveying, cartography, photogrammetry and their applications in mapping, data management, visualisation, navigation, standardisation, open- source software, open geospatial data, internet connectivity and cloud-based services is in great demand. In addition, recent advancements in Information and Communication Technologies (ICT) such as Machine Learning and Data Science have made the public and private sectors to seriously consider the GSTA as a disruptive multi-disciplinary technology to stimulate action in all critical areas of importance.

Many institutions especially in the developing and underdeveloped countries are lacking in strategy to sustain GSTA projects as the majority of the geospatial applications are project based. This has created challenges in maintaining and upgrading GSTA infrastructures, as well as in updating geospatial data and strengthening human resources after the completion of the project. Government agencies and industries have been finding it difficult to retain qualified professionals for a longer term in the field of EO and GSTA. This paper reviews various aspects of capacity development in geospatial technologies to take a holistic view of preparing the required talented workforce at different levels of competency.

The rest of the article is organised as follows. Section 2 describes the intent of different stakeholders who wish to exploit the GSTA. Different levels of competency at their levels are discussed. Section 3 covers briefly the different types of CD modes and also methodologies presently known for implementing these modes. Section 4 deals with curriculum design elements based on two levels of body of knowledge for GSTA. Section 5 stresses the today's demand for coordination in delivering CD programs effectively and Section 6 on the analysis of gender diversity issue in GSTA especially in the developing Asian countries. Concluding remarks are given in Section 7.

2. SECTORS OF GSTA USERS & THEIR NEEDED COMPETENCY

Capacity development is described as a process of initiating and sustaining individual and organisational change (UNEP, 2006). The process should aim at increasing their abilities by:

- identifying needs and building on existing capacities;
- formulating clear objectives strategies to meet needs;
- studying and choosing the right from a wide range of CD approaches;

https://doi.org/10.5194/isprs-annals-V-5-2022-9-2022

- targeting the right set of specialists to build a critical mass;
- making the training-of-trainers plans; and
- organising CD programs to reach national and regional levels.

If the capacity is the 'means' to plan and achieve, then capacity development describes the 'ways' to those means. The user community can be broadly brought under three categories - based on their intended technical and technological capacities and learning interests.

2.1. Operational Users:

A majority of user community at present falls under this category. The operational users or technicians are the people who are to transfer the data into knowledge for use in real-world environment. This sector of users is, however, strongly dependent on laid-down standard operational procedures (SOPs) which in turn depend on how transfer of software/hardware technology is complete from research desk to practical use. The transfer of technology plays a crucial role in bringing confidence in the user community in relaying geospatial data to intended applications. These users are the ones who would also bring out issues and limitations in the existing systems, thus playing an important role of feedback mechanism in EO data and processing chain. A good example is defence data operators working with high-resolution imagery to know about any illegal movement around the international borders of their country. Though highly desirable, their profession does not demand EO imaging strategies, planning and importance of spacecraft platform parameters etc. in any great detail for their intended use. Their primary demand is the 'know-how' about to process the satellite instrument data and combine these with relevant data from other sources including ground survey data needed to prepare the reliable information from analysis ready data (ARD) in a customised way for decision-making or trigger action. The ARD is developed to mount in different software system platforms seamlessly with international data compatibility guidelines (CEOS, 2021).
Developing human resources capacity for this group demands different pedagogical approach (Vyas, 2020). The users involved here are typically working mid-career professionals holding already undergraduate and/or graduate degrees from their earlier education and working with specific objectives of government, industry or in academic institutions, but eager to learn GSTA operational procedures through hands-on training relevant to their requirements and operational use.

2.2. Algorithm Developers:

As the title implies, developers are an elite "think-tank" group comprising of scientists and researchers who will specialize and become strong expertise in entire chain of GSTA at different levels of processing information and have the potential to develop novel techniques. They are always on continued pursuit of improving their innovative skills, thus playing anchoring role in advancing novel ideas in GSTA with their innovative skills to solve present-day limitations. To meet the expectations, a strong command in theory and practical is essential foundational undergraduate courses of science, technology, engineering and mathematics (STEM) subjects. A long-term dedicated effort is required to build this sector group nationwide in order to understand their national specific conditions and demands.

The best way to develop this group is to "catch them young" after the secondary school and university level learning, and inculcate deep interest in basic skills of GSTA through systematic educational programs. There are, of course, many drivers that motivate the youth learners to select their career to any specific professional field. The employment assumes that the career chosen should provide 'a place for everyone' when it comes to multi-disciplinary fields like remote sensing and its diverse applications in forestry, land cover surveying, urban planning, geology and resources management etc. The above- mentioned learners are best prepared to uptake GSTA as their professional career when their schooling and university level education involve them to provide preliminary, basic and advance levels of GSTA elements in their curricula and extra- curricular activities. A majority of them may choose to be future educators/trainers, again beneficial to meet the ever-increasing workforce demand.

2.3. Decision Makers

Not the least of the GSTA users' list are senior scientists, administrators and government policy makers who would like to access all the information that are available for prediction of their national resources' status and forewarning as well as post- action plans for example, after natural disasters. This sector of user community prefers "plug-and-play" data services on a customised software platform developed by space agencies or industrial vendors. They are neither concerned on details on geodata processing, instruments' calibration/validation elements nor interested in base-line algorithm development steps while using the services to get the best earth observation products. They are keen, however, to receive these EO 'actionable' products that meet the 'fitness for purpose' of the application in question and services on time – almost real-time in the case of disaster assessment and mitigation analysis – and demanding quality-assured information products and services at the time of decision making. In other words, their interest is to concentrate on the information content available or the lack of it from the data rather than trying to work around with the data to convert by themselves into final ARD products and actionable services. This puts the data providing agencies a huge task of bringing their data into a customer friendly, interoperable with other satellite products, reasonably comparable with ground measurements as well as interchangeable or blending smoothly with other sources of information. They are, however, interested to get appraised about the recent trends in imaging technologies and their benefits as well as shortcomings over existing operational solutions.

2.4. Competency levels in GSTA learning :

The term 'competency' is the quality or state of being functionally adequate or having sufficient knowledge, strength and skill. This is the prime objective of capacity development. This also implies that the competence is not a passive state of adequacy, but is part of a continuous process and in that the human resources are central to development. As seen in the above section, the different learners desire to have their own capacity with different learning objectives. It needs to be considered that CD has multiple levels of learning: building awareness, building analytic capacity and building decision making capacity, as well as strategies for human and institutional capacities sustainability. Each one is equally important, but may involve different stakeholder groups and require different strategies (Figure 1).

A lot promotional activities that are currently pursued through tutorials, workshops, seminars, conferences and very short-term courses (less than a week) remain at a raising awareness level. It is, however, the analytical and decision making capacities that are needed to sustain a constant process of change. Whereas the human capacities are critically important, institutional capacities that remain in place as humans move on are essential for a process of organisational change. Analytical, decision making and institutional capacities are more difficult to develop, monitor and sustain. This requires a continuous pursuit at institutional level with a wide range of CD approaches (UNEP, 2006).

2.4.1. Basic Competency:

As the name implies, this competency is a fundamental one to the understanding of geospatial technologies and their applications in various areas mentioned above. It should therefore be treated as a 'must-know' competency for all learners irrespective of whether they come from academics or industry or government organisations.

Learning objectives: It is primarily to motivate the learners in order to stimulate interest in them to learn how the geospatial technologies are indispensable in day-today affairs and their important benefits. To understand the fundamental aspects of remote sensing, GIS and GPS systems descriptively with minimal essential details on theoretical elements, but with some illustrious examples and possibly some outdoor activities. *Pedagogic objectives* : The teaching approaches would differ from one set of individuals to another, depending on their educational background. For example, for secondary level students, it is best done with the help of gamification techniques (Section 3.4), while for working professionals, it is done effectively by highlighting successful stories or case studies of the applications wherein GSTA has had a significant impact in taking decisions.

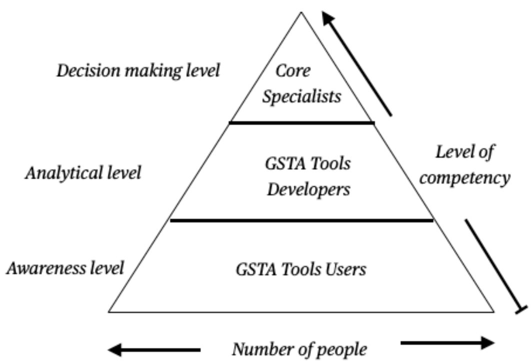

Figure 1. Users and levels of competencies

2.4.2. Analytical Competency

This competency is fundamental to creation of workforce supply chain for all important operational and developing theme-oriented modelling of the Earth system. This can be accomplished in two tier levels - digital and workplace competences. These are as described as below.

***Digital Competency**: The* 'digital' competency is about building the confidence on critical usage of the full range of digital information technologies. This includes methodologies for collecting data from the ground-based sensors from either in-house or from web portals, as well as satellite and other layers of information needed for analysis. This is especially essential for all operational users of geospatial technologies. These users are expected to follow laid-down standard operating procedures (SoPs) in basic problem-solving in assigned tasks such as digital mapping, satellite data pre-processing and classification, overlaying and extracting multiple data layers etc. This in turn demands the knowledge of data sources for extraction, processing, information retrieval and storage the relevant information etc. using geospatial tools and techniques following the SoPs.

Learning Objectives: Learn to apply digital techniques in the laboratory on geospatial data for deriving primary and secondary levels of information that are demanded by decision making process.
Pedagogic Objectives: Hands-on exposure of operational procedure of using the geospatial tools such as image registration and processing, atmospheric haze compensation, data classification and information fusion etc. An exposure to web-based services available for EO data downloads and other ground measured instruments data such as automatic weather stations data would be highly desired.

Workplace Competency: This competency is a description of a required skill, attribute or behaviour for a specific job at hand used to define and measure an individual's effectiveness. The workplace competency has many facets - individual excellence, operational excellence, organisational excellence etc. Though it may look similar to digital competency, here the learners are mid-career working professionals who have their expertise in their respective specialisations, but wish to explore new techniques and apply these to solve standing issues in their applications. They also have an inclination to upgrade their knowledge through continuing their professional education. This involves generating new, unique ideas and solutions; applying innovative and creative thinking processes; making timely and sound decisions that lead to results; looking beyond the obvious to perform honest analysis and see hidden problems; uses rigorous logic and methods to solve difficult problems with new approaches. The new knowledge would help in arranging information and files set in order; leverages technology required to accomplish work; keep current on emerging technologies, changes in software and new applications as pertinent to their jobs and utilise electronic resources securely, protect all important data from vulnerability.

Learning Objectives: Learn new technologies and instrumentation that are relevant to their field of work to develop special skills to innovate newer and efficient approaches over the conventional techniques, models and measurement methods.
Pedagogic Objectives: There are two ways depending on intended depth of knowledge to be imparted in short term and long term courses. Short-term courses of duration typically from 2-4 weeks are conducted in advanced themes with an objective to promote awareness cum skills development ('skills/ awareness development') on state-of-art information on the selected themes, with special emphasis on hands-on training for working professionals. This includes senior working level professionals as well as decision makers and teachers as well. The use of Geo-information technologies to coastal and marine disaster management and climate change, Remote sensing with unmanned aircraft systems, 3D virtual modeling of buildings and monuments, Microwave and LIDAR and their applications, Space weather are specially demanded by alumni of training institutions. The training would involve class-room lectures in the forenoon and practical sessions in the afternoon. To avoid boredom of stretched class-room hours, the theory and practical sessions are connected in alternate hours.

Long-term courses typically of a duration of 9 months to 1 year are suited to young and curious mid-career professionals working in academic and government sectors in their countries are given an intensive training in all the GSTA disciplines. The end of this course leads to certification of a post-graduate diploma or a professional degree that helps these learners for career building in their respective working places and would lead to job satisfaction and promotion. This type of courses are typically done in modular structure. For example, the 9 month PGD course offered by UN-CSSTEAP would have 3 modules each for a duration of one month (Kumar and Aggarwal, 2018). The first module is common and covers technological aspects of the geospatial technologies. The second module provides theme-specific modelling and applications of the GSTA in agriculture, forestry, water resources etc. The last module is devoted to projects.

2.4.3. Decision Making Competency:

This competency is about acquiring higher order skills into the learners who will become "think tank" members subsequently. The higher order skills can strive individuals to gain problem-solving capacity. This involves in general three factors: a) high academic ability; b) analytical skills and c) mastering concepts. An individual with high academic ability tends to have good critical thinking skills. Analytical skills refer to the ability to collect and analyze information, problem-solve, understand constraints of data and/or methods and arrive at the most accurate solutions to the existing ground scenario. The deeper the understanding of fundamental and allied subjects concepts better the learners' ability to analyze the circumstances surrounding the occurrence and differing point of view about the occurrence. Building the academic competency determines the scope of any new developments and advanced ideas that could trigger growth in both scientific and technological elements in the organisations and industries.

Learning Objectives: It is important to make the decision maker learn to 1) build relationship between different types of data, 2) merge multiple data layers to combine and produce the most acceptable synthetic information, 3) weigh outcomes from potentially competing alternatives and 4) forecast (NRC, 2002). *Pedagogic Objectives*: Command in understanding spatial decision support tools such as GIS is essential. Second emphasis is on linkage of data with analysis tools. The use of spatial analysis functions in GIS modelling is quite critical to produce a new synthetic layer by data merging for vital decision making related to risk assessment. Examples like how various habitat, human population, and climate data layers when merged can provide a vector-borne disease risk map as a product can be shown as hands-on. Spatial decision-support systems also can involve numerical models, including forecast models that evaluate through simulation in map form various alternative scenarios based on different policy options.

3. MODES AND METHODS OF CD

There are basically three broad categories of capacity development deliverable modes. Which mode is best suitable depends upon the learning objectives (purpose of learning) of the capacity building program, duration of the program as well as resources (both human and access to high speed internet), before deciding which delivery mode is the most appropriate to meet the learner's demands (WGCapD,2017): *onsite, online and blended (online & onsite)*.

3.1. Onsite Learning

The learners and instructors are co-located in the same time and at same location for a face-to-face learning process. There are many ways in this mode of learning:

- Instructor-based class-room learning
- Hands-on learning
- Learning by caravan
- Cross-border learning

3.1.1. Instructor-based class-room learning:

This traditional face-to-face approach by far is the most demanded and widely used method as far as the GSTA and its related theme subjects are concerned. A subject expert prepares a lecture style power-point presentation to share his/her individual experience learnt through research and working knowledge on the subject to a group of learners. Personal interaction amongst the learners and strong relationship building between the instructor and the learner are clear benefits of this method. Shortcomings are its lack of scalability. This mode gets complicated when the learners' group size becomes too big for the one-to-one interactions with all. Yet another major drawback is its rigidity. If some learner with his/her strong educational or working experience outpaces the fellow learners and willing to learn further ahead of others, there is no personalized learning path for such a learner.

3.1.2. Hands-on learning:

This mode aims to create a simulated work environment to permit the learner to 'learn by doing' and perform tasks, making decisions or using equipment of appropriate. This directly drives learners into practical rather than exposing excessive conceptual elements. Here, learning is implemented by a combination of observations or instructions from the instructor, explanation of the methodologies and direct practical usage. Benefits are: It makes the learning starting from the day one and allows the learners much needed 'settling' time when they come from different places and working environments and boost their knowledge recollection. Shortcomings are: If the hands-on starts from the very beginning of capacity building, some learners may struggle to understand intricacies of their learning the exercise without first having the context of learning, if they are doing the exercise for the first time. Also, the instructor does have little time to understand the capacity of the learners if this method is effective to them.

3.1.3. Learning by Caravan:

As the name implies, 'caravan' is about migrating CD programs from one place/country to another on rotation. The primary motivation is to bring awareness of applications of geospatial technologies specific to the theme interested by the nation for its local and regional development programs. The CD program is managed under the guidance of well accomplished institutions having support of theme experts to monitor and guide the progress. Such training is best effective through a coordinated effort between these experts and the local coordinating organisers to benefit their scientists and engineers working in academics, government, and industry sectors. This training has many advantages in reducing international travel cost, attracting a larger audience to such programs. This also provides another opportunity for the local organising institutions to promote national geospatial technologies with participating various organisations. A good illustration is the Caravan training supported by the JAXA. Since 2006, ISPRS WG VI/6 was collaborating with Asian Institute of Technology, Thailand, GIC and JAXA in conducting as many as 17 such programs between 1997 and 2005 in nations across the Asian region (Samarakoon et al. 2008). The UN-affiliated Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP) in collaboration with UN-SPIDER has conducted two such programs in Myanmar in 2017 and 2019 and supported its counterpart in China from 2017 on the applications of geospatial technologies for post disaster rapid assessment (Kumar and Aggarwal, 2018).

3.1.4. Cross-border Learning:

In this type of learning, there is movement of people, knowledge, programs, providers and curriculum across national or regional jurisdictional borders (Knight, 2006). Cross-border education (CBE) is a subset of "internationalisation of higher education" and can be an element in the development cooperation projects, academic exchange programs and commercial initiatives. Though the learning by caravan appears to fall in line with the CBE objectives, the caravan distinguishes itself by virtue of its short-duration, its low-intensity, promotional nature of its activities. On the other hand, the purpose of the CBE is to provide training/education targeted at middle level professionals with stronger eligibility criteria, age limit etc., and follow academic certification protocols like tests, seminars, mini-projects to improve the learner's proficiency. These programs are financially supported either by international organisations or government departments of countries with a common motive to promote capacity development in selected topics the personal from developing and/or underdeveloped countries. A good illustration is the Indian Technical and Economic Cooperation (ITEC, 2022) Programme, a fully funded initiative by the Government of India, has evolved and grown over the years with participants from 161 countries in Asia, Africa, East Europe, Latin America, the Caribbean as well as Pacific and Small Island countries are invited to share in the Indian developmental experience acquired over six decades of India's existence as a free nation. Also, the UN-affiliated CSSTEAP conducts 9-month long post graduate diploma courses in five different themes of GSTA and a two-week short program on small satellite missions. More than 2000 participants from 36 Asia-Pacific (AP) countries and 19 countries from outside the AP region at its nodal centres were benefitted (Kumar, 2019).

3.2. Online Learning

Online or E-learning, by definition, is a computer-based learning system that enables the learner to learn from anywhere with the power of present day internet and web technologies (Oye et al. 2012). There are two ways in e-learning - synchronous and asynchronous.

3.2.1. Synchronous e-learning:

Instructions occur live and in real-time supported by specialized video conferencing solutions such as Go-to-Meeting or YouTube Live or alike audio-visual methods. In a sense, this format of learning is similar to instructor-led classroom method discussed above, with an exception that the neither the teacher nor the participants do physically present in one room, but virtually present through internet or satellite-based networking system. The typical functioning mode of the web-based learning is that only an instructor has the right to speak; learners due to large numbers attending from remote locations use text chat to send their questions and give feedback. However, there are recent learning management systems (LMS) that allow two-way interactions in selective manner.

The most striking benefit of all with the e-learning is that it has reduced the learning restrictions posed due to location and time. In the last two years due to Covid-19 imposed restrictions on face-to-face interaction, the world was fully dependent on e-learning mode of education. E-learning is the best and the only way to reach masses of learners across the nations in a cost effective manner. One of the serious limitations of the e-learning methods in learning practical skills. Even though there are new software tools evolving to innovate practical studies, it has not been found so effective and comparable to face-to-face counterpart. The web-based learning courses go unmonitored, especially under conditions like "learn from home"; it is hard to know whether the learners are truly engaged with the lecture due to no eye-to-eye contact between the instructor and the remote learners. There are many intelligent LMS being developed that would add new features like quizzes, interactive modules etc. to keep the learners active.

3.2.2. Asynchronous e-learning:

Video-based learning, more popularly known as massively online open course (MOOC), has emerged as a strong alternative to synchronous method, thanks to enormous amount of effort made by many space organisations and other global institutions to come up with many innovative video lectures with animations to demonstrate the geo-spatial technologies and their applications. With fast internet availability and smart phone affordability, the video learning is potential to replace long documentation movies and dry onboard handbooks with its interactive and engaging content.

Any-time, any-where learning is one of the most attractive features of the MOOC. Unlike the in-person instructor-led classroom learning or synchronous web-based method – both requiring some infrastructure setup and a schedule, video-learning content is always readily available all the time. The interested learner can watch these videos anytime anywhere on any device. The multiple revisiting of the video lectures and demonstrations for better clarity adds a special feature of the video learning, besides the flexibility to change the content much needed to emerging technologies such as the GSTA.

3.3. Blended Learning

This approach tries to gain from the best of both e-learning and face-to-face classroom methods (Jones et al. 2007). This is generally done in two parts: the theory and conceptual understanding would be done through online mode as either video or webinars as above. This is followed by again e- learning mode but on practical classes with the help of field expert demonstrating the practical skills that are required in the field studies. The educational institutions can then carry out contact classes for face-to-face hands-on with the support of distributed learning centres. This can be achieved by engaging many educational institutions and training organisations to schedule and conduct these exercises following an agreement to implement a set of laid down procedures to conduct these skills development exercises.

3.4. GSTA Capacity Development Methods

A wide range of approaches is available to build capacities, including gaming methods, training, formal education, capacity building projects, networking and others (UNDP, 2009). Which

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approach is the most effective one would strongly depend on the specific talent to be achieved. As shown in Figure 2, there can be possibly six levels to the GSTA learning. A training workshop usually can go as far as building human capacities at awareness raising or soft skills development level. If specifically designed, training may also succeed to build analytical capacity. There is also, however a tendency to call a wide range of formal meetings as ‘capacity building’, which rather are policy dialogues, discussion workshops, regional meetings etc. For such activities there is no clear capacity development objectives defined as none of its methodologies are used. It takes much more for an adult to acquire new knowledge and skills than by just listening to a presentation in such gatherings. In addition to seeing and listening, adults usually need real life experiences to acquire new abilities. For example, if a workshop is to more effective, it should be carefully designed, moving as much as possible from the presentation/discussion style into an interactive one, using exercises, case studies, field visits and other elements of experimental learning to actively build the capacities. The effectiveness of training activities could be further increased, if workshops would not just be one-off events but be embedded in long-term capacity building program, comprising a series of workshops that reflect the beneficiary organisations’ priorities, and using a range of capacity building approaches in parallel.

There are two levels by which capacity development programs to be targeted: 1) at the human level (human capacity development) and the other in institutional level (institutional capacity development). These two levels influence each other in a fluid way – the strength of each depends on, and determines, the strength of the others.

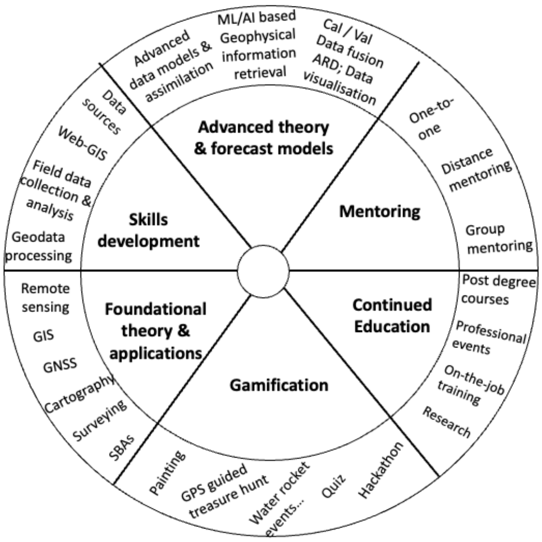

Figure 2. GSTA learning wheel.

At the individual level: are the skills, experience and knowledge that allow each person to perform. Some of these are acquired formally, through education and training, while others come informally, through doing and observing. Access to resources and experiences that can develop an individual’s capacity are largely shaped by the organisational and environmental factors described above, which in turn are influenced by the degree of capacity development in each individual.

At the organisational level: refers to the internal structure, policies and procedures that determine an organisation’s effectiveness. It is here that the benefits of the enabling environment are put into action and a collection of individuals come together. The better resourced and aligned these elements are, the greater the potential for growing and sustaining the required capacity.

4. BODY OF KNOWLEDGE & CURRICULUM DESIGN

The Body of knowledge (BoK) commonly refers to as core teachings and skills required to work in a particular field or industry. Experienced professionals of the discipline outline what is needed to achieve the competency levels and that forms the foundation for the curricula of most professional programs or designations. People seeking to enter the profession must display their mastery of the body of knowledge in order to receive accreditation that enables them to practice these skills. There are two levels of BoK, as explained below.

4.1. Top-down BoK Approach:

DiBasie et al. (2006) proposed a professional domain model for the GSTA BoK and curricula required at undergraduate /graduate level university students that may lead to building this knowledge in systematic educational programs. A detailed curriculum is designed to cover all the required subjects to develop the capacity of these learners starting from the fundamental elements of science, technology, engineering and mathematics (STEM) and their impact in thematic applications. This top-down approach sets out the most ideal model for realizing core specialists’ group which is in the apex of competency pyramid (Figure 3). A variant to this model was proposed for extending it to active optical sensors as part of EO and geo-information (Dubois et al. 2021).

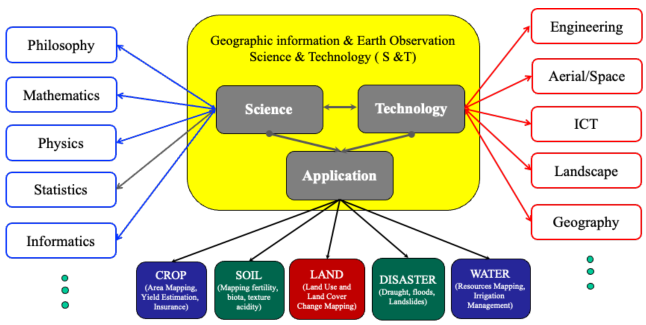

Figure 3. GSTA Top-down BoK for development of core specialists (modified from DiBasie et al. (2006).

4.2. Bottom-up BoK Approach:

Molenaar (2002) emphasised a context-process model that keeps the intent of learners with different domains and time available as priority, and segregates the content of the CD program to meet their interest. This model perfectly suits to the working mid-career professionals in diverse fields who would like to know the relevant topics with emphasis of different topics to be learnt in a short period of learning phase and may wish to continue to improve their educational qualification. The context-process models for the capacity building programs on introductory programs on geospatial information management and on urban planning and land administration are as shown Figure 4. Clearly, the emphasis for both these programs differ significantly and match with expectations of the learners. The curricula are therefore given weightage of the context accordingly.

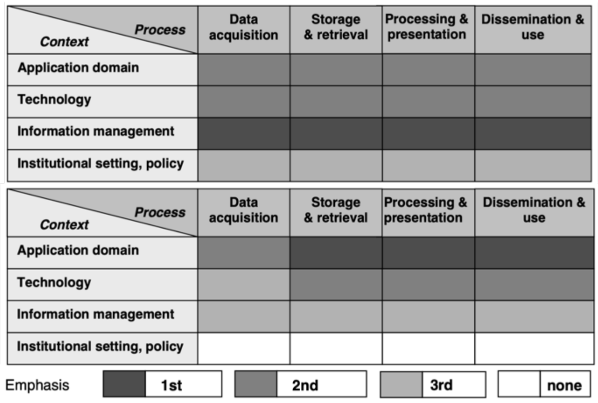

Figure 4. The bottom-up BoK model best suited for mid-career professionals for Geospatial information management (top) and for Urban Planning and Land Administration CD program (after Molenaar, 2002).

5. FRAMEWORK FOR COORDINATED CD

No technology could sustain long and provide opportunities for many innovations until it is put into use either directly and indirectly on applications that will benefit the society encompassing human and animal kingdoms and their environment. Earth observation (EO) is the gathering of information about the physical, chemical, and biological systems of the planet Earth. It can be performed from data acquired from remote-sensing technologies as well as by ground-based techniques. It is not just gathering but making use of it to monitor and assess the status of and changes in natural and built environments of great importance. Obviously, it requires committed effort and international cooperation to achieve this task. Realising this, many international organisations (UN, CEOS, GEO, WMO) and different NGOs (ISPRS, IEEE, ISRS, ACRS, APRSAF etc.) offer a good number of opportunities at regional scale or at global scale. However, while many learners have gained sufficient knowledge from these opportunities, many nations could not build yet a lasting institutional capacity from these programs. Insufficient coordination among the stakeholders leading to duplication of efforts, lack of results-oriented framework to measure the success of CD, oversupply of CD to some nations, lack of a national strategy to retain trained staff and involve them in best possible roles to put their knowledge to optimal solutions etc. are some of the shortcomings in this multi-institutional training effort. This can be achieved with a framework for coordinated CD consisting of four distinct stages, as shown in Figure 5: harmonising, planning, execution and delivery (Kumar et al. 2020).

In order to harmonise coordination amongst various institutions, it was recommended to build a common database that record all activities that would allow countries to review their existing talent and plan to enhance the workforce competence in newer areas. In planning stage, it was proposed to set up a space capacity development advisory board (SCDAB) to assess region-specific demands and identify experts for regional curriculum development. In execution phase, a proper assessment of existing institutional capacity established across the globe by various organisations was to be done and upgrade their existing infrastructure in line with SCDAB recommendations. Deliverables could be achieved by one of the suitable methods discussed above in Section 3.4.

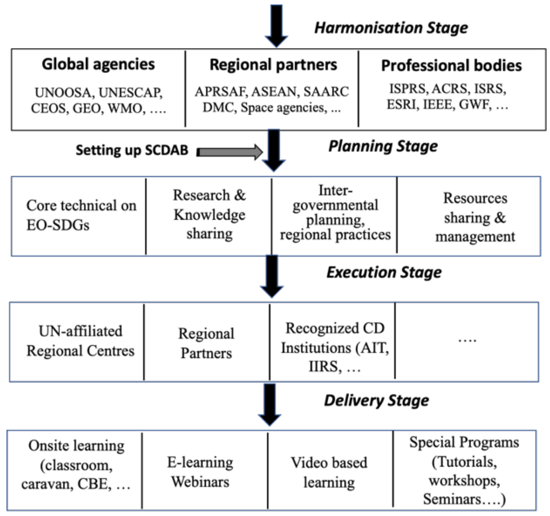

Figure 5. A conceptual framework for coordinated CD (modified from Kumar et al. 2020)

6. GENDER DIVERSITY IN GSTA LEARNING

Goal 5 (Gender Equality) is a stand-alone gender goal in UN-Sustainable Development Goals and is devoted to ensure the benefits of CD reach the female gender (UNOOSA, 2012). The new initiative 'Space for Women (S4W) aims to empower the competency of the women in all sectors discussed in Sec. 2. Educating women can yield in teaching and imparting values to their families and their nations as a whole (Botella et al. 2019). A recent study has shown that women participants prefer to enrol more in physical science and technology over engineering /mathematics oriented satellite communication/ navigation systems courses in the Asia-Pacific region (Kumar et al. 2021). There are also diversity in competence in learning the GSTA across the Asian countries, thus requiring to develop new strategies for handling multi-cultural, multi-ethnic classroom environment. Many remedial recommendations were put forth by various researchers to improve female enrolment in STEM. In addition, and in particular for promoting S4W in Asia, it was suggested that initiation of joint education programs with leading institutions in participants' countries in the region would reduce the duration of women participants to be away from their homes, promoting standardisation of STEM curricula and continued mentoring of educators and trainers as well as preparatory learning of English language and lecture material prior to training.

7. CONCLUDING REMARKS

In this article, various aspects of capacity development pertinent to geospatial technologies and their applications are briefly reviewed. For sustainable development of workforce, the importance of assessing the users' requirements and their expected competency after training/education is stressed. Both online, face-to-face as well as blended modes of conducting the capacity development programs are described. A number of pedagogic approaches for imparting knowledge were displayed in a learning wheel. Two ways of developing the required curriculum design to meet the end users' objectives are brought out. The importance of holistic development of workforce across the nations by a coordinated effort by national, regional and international organisations/institutions was stressed to maximize the benefits of geospatial technologies for realising global flagship programs like the United Nations' sustainable development goals. Finally, the recent findings to increase the enrolment of women in geospatial technology capacity development programs are briefly covered.

ACKNOWLEDGMENTS

The author gratefully acknowledges Dr. A.S. Kiran Kumar for his constant encouragement and guidance during the author's tenure at IIRS and CSSTEAP. He also sincerely thanks all the faculty members at these institutions for their dedicated support in various capacity development programs. Support and advise from Dr. Shirish Ravan, and Dr. Simonetta Di Pippo, UNOOSA on many international programs are acknowledged with thanks.

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