

MULTI-LEVEL EDUCATION AND CAPACITY BUILDING FRAMEWORK FOR TECHNOLOGY ADAPTATION

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ABSTRACT:

Advancements in the Geospatial Technology has brought about benefits to various fields in science and technology. The education and the capacity building of geospatial technology plays a very important role within these fields. The current practice of the education is basically dominated by the teacher, huge syllabus, non-relevant knowledge and having very little opportunity for the discussions between the students and teachers. Instead of the unidirectional, monolithic, rigid and traditional teaching in practice, it requires a change to dynamic, evolving, in-process and gradual system of learning to shape the knowledge society. This generates creative, innovative human beings to train them to perform based on the scientific reasoning and empirical evidence in their respective fields. In order to develop, there are three important components: content, practice and cross-cutting to be established as a strategy in the data savvy environment. The 'content' may shift to more emphasis on higher order skills of constructing explanations, the 'practice' would enhance critical thinking as well as synthesis and 'cross-cutting' would synergize the performance expectations. Hence, the modified education and capacity building programmes advocate to move to a competency based model and the imperatives motivate the better use of the technology. This paper explains multiple levels that exists across academic, research and practitioner community that have potential to benefit from geospatial technology and it determines appropriate curriculum, pedagogy and evaluation strategies. It also maps an appropriate framework and approaches for multi-level education and capacity building considering the recent developments in geospatial technology.

1. INTRODUCTION

Geospatial technology domain has witnessed several disruptions in recent past, from conventional surveying, cartography and photogrammetry approaches to most recent AI powered VR/AR capabilities made available to anyone with a connected device. The geospatial technology being inter-disciplinary in nature is applicable in diverse areas of science and technology including significantly crucial areas such as those of governance, peacekeeping and healthcare sectors (Rawal, Gupta, & Vyas, 2019) (Convergne & Snyder, 2015) (Porcasi, et al., 2012). Knowledge Transfer and capacity building in Geographic Information System(GIS) in context of spatial data within Information Systems (IS) in natural resource management like coastal management is very powerful (Stojanovic, Green, & Lymbery, 2010). Easy accessibility to high-resolution data products, mapping, data management, visualization, navigation, standardization, open source software, open data, internet connectivity, cloud based services has converted an ordinary light-weight device into potential Geospatial technology laboratory. This provides window of opportunity to impart advanced geo-spatial skills to students, researchers and professionals in various academic domains and disciplines of practice. The tapping benefits of advances and developments in the Geospatial technology to all at the fullest requires different types of knowledge and skills that goes well beyond the conventional educational approaches in any single academic discipline. The Indian scenario of student technical training and capacity building through initiatives like Remote Sensing & GIS Programme by ISRO is very encouraging (Remilla & Kishore, 2018). Multi-level approach is being implemented across India (Pendyalala & Vijayan, 2018) shown as web based multilevel

implementation plan for training using module based learning. E-learning has emerged a successful approach in this regard (Raju, 2012) (Gülch, Al-Ghorani, Quedenfeldt, & Braun, 2012). Theskills and core competencies are needed to be taken into consideration for curriculum development in many domains in Science and Technology and training be designed accordingly (Pistoria, Dressler, Budnitz, McKean, & Amin, 2006). This kind of multi-level interventions in training pose some challenges (DiBiase, et al., 2010) (Johnson & Sullivan, 2010) (Nastasi & Hitchcock, 2009).

2. OBJECTIVES

The aim is to identify multiple levels that exists across academic, research and practitioner community that are or have potential to benefit from Geospatial technology and to determine appropriate curriculum, pedagogy and evaluation strategies for each level.

(a) To identify multiple levels of competency requirements of Geo information theory and practice across diverse disciplines; (b) To study current state-of-the art in standardization of curriculum, pedagogy and evaluation strategy within Geospatial technology field and other pure and applied disciplines; and (c) To design and develop role and level specific recommendations of curriculum, pedagogy and evaluation strategy at multiple levels of competency.

3. METHODOLOGY

To attain the proposed objectives of the study, suitable methodology included: (i) Intense Literature review-based identification of parameters and indicators to assessment; (ii) Focus Group Discussion(FGD) and brainstorming meeting; (iii)

Mapping of appropriate framework for multi-level education and training. This multi-level comprises of academic, researcher and practitioner community relevant to Geospatial technology also to determine: (a) curriculum (b) pedagogy and (c) evaluation.

4. ANALYTICAL FRAMEWORK

As mentioned in the methodology, the objectives were to be achieved from the systematic analysis the functional attributes of multiple level target groups. Skills, knowledge, technical expertise are different in different target group and individuals, for example, familiarity of programming languages, algorithms, data management, internet protocols, network protocols, standards, etc. is though gradually becoming essential in many fields may not be necessarily known to every target group. So, as first step towards solving the problem is to identify and characterize all the possible levels of skills and competencies that are required by the students and the researchers that may benefit from technology education and training. Past works have used Knowledge Areas (KA) along with fundamental and core competencies for the training curriculum development in Geospatial technology (Plessis & Niekerk, 2013) (Plessis & Niekerk, 2014) whereas, we intend to include individuals non-specialized in Geospatial technology as well, who belong to different age groups. Education outcome indicators are subject to cognitive, motivational, and socio-cognitive components and depend on cross-curricular competencies (Moskowitz & Stephens, 2004). As a result, based on criteria:(a) level-of-education, (b) technology skills, (c) impact, (d) purpose, (e) resource availability, and (f) familiarity with theory, we classify the target groups as school students, undergrad students, graduate students, researchers, academicians, government, Industry and NGOs as shown in table 1.

	Level of Education	IT Skills	Impact	Purpose	Resources	Theory
School Students	K-12	Limited	Individual	Awareness	Low	Low
Undergrad Students	2 Years College	Limited	Individual	Basic Skills	Low	Medium
Graduate Students	Degree/Diploma	Medium	Individual	Advance Skills	Low	High
Researchers	Masters	Advanced	Individual	Research	Medium	High
Academicians	Masters/PhD	Advanced	Students	Teach	Medium	High
Government	Degree/Diploma	Medium	Citizens	Decision making	High	Low
Industry	Degree/Diploma	Advanced	Customers	Service/Product development	High	Low
NGO	Degree/Diploma	Limited	Focus Group	Decision making	Low	Low

Table 1 : Different target groups

Some level of technology capability is useful right from the school level all the way up to research, industry and practice in various disciplines. While exact determination of competence requirement for each role is an ambitious undertaking, it is certainly possible to characterize the levels at a very coarse level. But generalizing at school level requirement, it can be assumed that individual's level of education may be anywhere between K-12, with very limited technology skills, individual impact, the purpose is mainly the awareness, with very low accessibility of resources (like datasets, tools, software, devices) and low familiarity with theoretical concepts. On the other hand, someone with a professional role may have university degree, with advance technology skills, capability to impact large customer base, responsibility for development with accessibility to most advance resources and familiarity with all the theoretical aspects in this domain. Between these two extremes there are possible many other levels as indicated in the table 1.

Once these levels are identified, the next step is to determine competency needs at different levels. The following table enumerates typical tasks performed in the domain of geomatics along with level of customization or adaptation needed at various levels. For instance, undergraduate level students use available models, tools, generic software packages and basic level processing, interpretation and visualization of data. Whereas on the other extreme, industry professionals may have to define their

own data model, collect their own datasets, and apply their preparatory techniques for handling in geospatial technology data in performing their role. Considering these aspects, it is evident that imparting education and training at these levels therefore must take in to account and adopt according to distinguishing characteristics of learners.

The training may have to be imparted at either individual or institutional level whether to academic, commercial, governmental or non-governmental entities while targeting to make learning easier and overcoming barriers through better pedagogical and curriculum development interventions (Ramasubramanian, 1999) (Agboka & Matveeva, 2018).

	UG Students	PG Students	Researchers	Academicians	Govt	Industry	NGO
Generate Data	-	-	-	-	Own	Own	Own
Acquire Data	Secondary	Secondary	Secondary	Secondary	Own	Own	Own
Process Data	Basic	Basic	Advance	Basic	Advance	Advance	Basic
Interpret	Basic	Basic	Advance	Advance	Advance	Advance	Basic
Compute	Basic	Basic	Advance	Basic	Advance	Advance	Basic
Model	Use	Use	Develop	Use	Use	Use	Use
Software Lib	Generic	Generic	Custom	Generic	Custom	Custom	Generic
Theory	Use	Use	Develop	Use	Use	Use	Use
Visualize	Basic	Basic	Advance	Advance	Basic	Advance	Basic
Use Case	Typical	Typical	Specialized	Typical	Specialized	Specialized	Specialized
Duration	-	-	Yes	-	Yes	Yes	-
Disseminate	-	Papers,	Papers	-	Open Gov	API	Reports

Table 2: Level of proficiency at each target group

Considering existing and potential beneficiaries of Geospatial capabilities, we have carried out preliminary FDGs and brainstorming sessions as mentioned in second step in methodology with various school students, undergraduate and graduate college students, academicians, researchers, practitioners, consultants, and employees of industry, government and non-governmental organizations. As a result of these sessions, mapping has been done with respect to total skills and core competencies in geospatial engineering as shown in table 3.

	Science Students	IT Business Students	Researchers	Academicians	Govt	Industry	NGO
Basic Concepts	✓	✓	✓	✓	✓	✓	✓
Geo Survey			✓			✓	
Vector Tools		✓	✓		✓		✓
Geo-Referencing		✓	✓	✓			
Geo-Statistics		✓	✓	✓			
Spatial Analysis			✓	✓			
Image Analysis			✓	✓			
Projections and Transformations		✓	✓	✓			
Raster Analysis	✓	✓	✓	✓			✓
Raster Calculations		✓	✓	✓			
Raster Visualizations		✓	✓	✓			✓
Simulation		✓	✓	✓			
Terrain Analysis		✓	✓	✓			
DEM/S	✓	✓	✓	✓			✓
Map Server			✓	✓			✓
Standards			✓	✓			✓
Programming	✓		✓	✓			✓
Library Development			✓	✓			✓
Customization			✓	✓			✓
Using API			✓	✓			✓
Cartography	✓	✓	✓	✓	✓	✓	✓
Live Dashboard			✓	✓	✓	✓	✓
Reporting	✓	✓	✓	✓			✓
Open Data			✓	✓			✓
Data Science			✓	✓			✓
GPS			✓	✓			✓
LBS Development			✓	✓			✓
Mobile Applications			✓	✓			✓
AR/VR Application			✓	✓			✓
AI and ML			✓	✓			✓

Table 3: Skills needed in target groups

It is obvious that all groups have varying levels of familiarity and accessibility to resources. It is to be observed that an industry professional may have access to all the resources, but may not have a clearly defined education and training program specifically suited for the job on hand. In a different scenario, with free availability of data sets, software packages and self-paced learning resources, one may have achieved enhanced competencies in Geospatial technology domain. However, it might be difficult for individual to clearly claim the competency due to lack of formal authoritative proof. The need to address these challenges leads to the third step in methodology: outcome of the systematic survey, literature review and experts' interview on all these fronts can be effectively mapped to curriculum,

pedagogy and evaluation requirements at each level which are the three core pillars of any education program to be effective as shown in figure 1. This approach of systematic survey followed by design and development of appropriate framework for multi-level education and training tried to cover needs of professionals, students and researchers at various levels in multiple academic disciplines and application domains.

	Curriculum	Pedagogy	Evaluation
Multi-Levels	Geoinformatics BoK		
	Domain-Specific Content		
	SOP and Best Practices		
	Product Documentation		
	Standardization		
	Instructor Led Delivery		
	Learning Motivation		
	Field Work		
Lab work			
Independent Activities			
Team/Group Activities			
Familiarity with Curriculum			
Integration in Practice			
Self-learning			
Professional Progression			
IP and Community Contribution			
School Students			
Undergraduate College			
Graduate Students			
Researchers			
Academicians			
Industry Professionals			
Government Employees			
NGO Employees			

Figure 1: Framework of mapping Curriculum, Pedagogy and Evaluation with respect to different target groups

With wide range of practical applicability, data, tools and services in Geospatial technology domain; all three basic pillars must reflect same coverage and agility to maintain relevance. Curriculum includes Geospatial Technology Body of Knowledge (BoK), Domain specific content, Standard Operating Procedures(SOP) and best practices, product documentation and standardization. With wide range of practical applicability, data, tools and services in Geospatial technology domain; all three basic pillars must reflect same coverage and agility to maintain relevance. Curriculum includes Geospatial Technology Body of Knowledge (BoK), Domain specific content, Standard Operating Procedures(SOP) and best practices, product documentation and standardization. The survey investigated uptake of various standard curriculums (NCGIA Core, UCGIS, etc.) and body of knowledge (like GI S&T USGIS BoK) defined by various organizations. Survey helped identify recommendations and best practices by relevant other organizations in accurately determining the competencies in the domain. Considering the individual stakeholder's requirement of domain-specific knowledge, the proposed framework also proposes ways to connect to domain which is not part of standard geospatial technology curriculum. The systematic survey identifies how various stakeholders are currently building capabilities in formal and informal settings and develop framework that may identify which of the learning resources, tools, datasets, and other resources will be useful at each level. On the curriculum front, relevant topics segments from standard curriculums and body of knowledge be identified right from the school level to advance professionals and for various practitioners. It is imperative to identify relevant learning resources in that specific domain. Similarly, Standard Operating Procedures(SOP), and best practices are specific to different domains, and different communities of practices, and therefore should be linked accordingly. For instance, students, professionals, volunteers working in area of watershed management requires additional familiarity in that domain, which may not be part of core GIS curriculum. Therefore, it is imperative to identify relevant learning resources in that specific domain. Similarly, standard operating procedures, and best practices are specific to different domains, and different communities of practices, and therefore required to be linked accordingly. Users are leveraging specific

products and services, and their documentation are also an essential part of the curriculum.

Pedagogical approaches include instructor led delivery, learning motivation, field work, independent activities, team & other group activities. In addition to surveying the learning resources, attempts have to be made to identify best practices and pedagogical approaches that are published in the form of articles and research papers in key journals, conferences, workshops and symposia in the field of Geospatial technology. Finally, evaluation strategies have to be identified at each level establishing familiarity with curriculum to include integration in practice, self-learning, professional progression, community contributions.

Scientific Computing Platform	Special purpose Lab Facility	Open Scientific Computing Platform	Open Scientific Data Cloud	Open Reusable Components
Scientific Workflows and Visualizations	Experiments and Results Restricted to the Lab	Scientific Workflow Sharing Platform	Interactive Reproducible Analysis Platform	Data Visualization Platform
Geospatial Data Sharing Platforms	Spatial Data Infrastructures	Open Government Data Platform	Linked Open Data	Community Contributed Mapping Platform
Geospatial Software and Services	Vendor Products ESRI, Bentley, Intergraph, Microdesk, Autodesk	Open Source Desktop GIS	Web Based Standard Compliant GIS	Plug in Based Desktop GIS
Survey and Photogrammetry	Conventional Survey and Photogrammetry	Mobile Applications ODK, KoBo, GeoODK, GIS Cloud MDC, NextGIS, MagPi GIS, SMART	Low Cost Survey-Grade Drone Mapping	3D / AR / VR Platform
Education and Training	Conventional GIS Reference Degree Courses Certificate Programs Professional Training	Geospatial Curriculum / BoK	Geospatial Technology Competency Model	GIS Courses MOOC

Figure 2: Identifying the state-of-art in Geospatial technology Landscape

Surveying and Photogrammetry is key component in Geospatial technology domain, therefore, state-of-the-art in this aspect determines how current practices have evolved from conventional approaches of specialized equipment to using features offered by mobile applications. This reveals novel approaches, tools, and best practices that can be potentially included in education and training. There are several building blocks which are shown in figure 2. State of-the-art in education and training helps identify how it has evolved from period of conventional textbook oriented instructor lead training to most recent models of self-paced training offered via Massive Online Open Courses. As seen with data, software and visualization capabilities, the sharing of computation power has also evolved over recent times. Open science platform allows anyone to utilize highly capable hardware resources via cloud based access. As with computational capabilities, data storage is also critical component in scientific computing. Open data cloud platform enables shared data storage capability at petabyte scale. Apart from hardware and storage, generic middleware capability is also useful in scientific computing, and equally covered by innovative platforms like FIWARE. Developments on the front of software and services related to handling and analysing geospatial data is another key aspect. Software and services range from proprietary vendor products to free and open source offerings. With large scale adoption of relevant standards and development platforms, it is possible to discover many specialized pluggable components that comes out of specific research project that can be leveraged by integrating them in popular desktop and web based environment.

Availability of spatial data has also increased with adoption to standardization at various levels of data management. Right from encoding, exchange formats to domain specific models, increasing number of data sharing effort not only by agencies

producing the data products, but also by end-users at different capacities was witnessed. National level spatial data infrastructure programs are established by governmental organizations across the globe. Additionally, with uptake of open data awareness, data from various governmental departments at local, town, municipality, state and central level is now made available. Most countries individually and at union level are now sharing datasets in open formats and also making is accessible via web services. In addition to systematic data sharing programs by governments, there are several large-scale community-driven data curation and sharing efforts that have evolved over time. Linked Open Data cloud in its current form provides machine readable access to large number of datasets, many of which are relevant to users. Projects like Open Street Map offers very robust and reliable access to mapping and navigation capabilities, which is contributed by community. As datasets are critical component of the Geospatial technology domain, it is imperative to determine and include ways to effectively incorporate them in overall education and training strategy.

Taking all the aspects in to consideration, there are few following approaches identified for multi-level target groups:

Target Group	Subgroups	Approaches
Students	Novices	Involving novice learners by popular talks, demonstrations etc.
	Fresh graduates	Emphasize on enhanced employability via skill developments
Researchers	Researchers	Emphasizing on research collaboration, exchange opportunities
	Knowledge Workers	Introducing emerging technologies, trends and practices preparing future demands
Academicians		Assisting them setting up labs, curriculums and data library
		Hosting regular meet-ups featuring practitioners, academicians, consultants, experts etc.
Industry Professionals		Skill updates program working with continuous education
		Hosting periodic walk-in facility to act as quick assistance / clinic for addressing challenges
		Hosting email discussion groups, social media community pages, to promote events, exchange of ideas
Government and NGOs		Emphasize on open source and open data

Table 4: Recommended approaches for target groups

The analytical study resulted in delineation of different target groups, which thereafter brought insights out of curriculum, pedagogy and evaluation based strategies for target groups and finally ended on the note of some recommended interventions which enhance their capabilities in this area.

5. CONCLUSION

Aligning with ISPRS mission for the development of international cooperation for the advancement of photogrammetry and remote sensing and their applications, this study results in a framework of multi-level education training in Geospatial technology to address needs of stakeholders at basic, professional and decision-making levels.

The target users for the outcome of this study is grouped in three levels. Conventional users that are familiar with Geospatial technology and have advance infrastructure, tools and capabilities. Second group is early adopters that are mainly on the applied side, leveraging the Geospatial technology in academia, research or practice with intermediate level infrastructure, tools and capabilities. The third group consists of users that are not yet having any kind of specialized infrastructure, resources or capabilities to handle Geospatial technology, but can potentially benefit a lot by developing familiarity. Therefore, the main target users are in this group, and spreading awareness and making Geospatial technology accessible. The paper gives strategies and approaches for multi-level target groups considering three basic pillars: curriculum, pedagogy and evaluation in specific domain of Geospatial technology education.

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