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LEARNING BY DOING: EXPERIENTIAL APPROACHES TO DEVELOPING DIGITAL AND ENTREPRENEURIAL COMPETENCES

Abstract

The geodesic sciences, encompassing geodesy, geoinformatics, cartography, remote sensing, photogrammetry, and spatial data science, stand at a critical and dynamic inflection point. Driven by the digital revolution, the field is undergoing a profound transformation characterized by an explosion of data volume (Big Geo-Data), velocity (real-time sensing), and variety (from IoT sensors to social media geotags), and the disruptive integration of advanced computational techniques such as Artificial Intelligence (AI), Machine Learning (ML), and cloud computing. Concurrently, societal demands on the discipline are escalating, requiring not only advanced technical solutions for climate monitoring, urban resilience, and sustainable resource management but also commercially viable applications that drive the burgeoning geospatial economy. This dual imperative creates a significant competence gap between traditional geodesic education, often rooted in theoretical principles and standardized software training, and the multifaceted expertise required in the modern workplace and entrepreneurial landscape. Graduates must now possess a hybrid skill set: deep **digital competences** (e.g., advanced programming, cloud-based geospatial processing, AI/ML application, data engineering) seamlessly integrated with core geodetic knowledge, and robust **entrepreneurial competences** (e.g., opportunity recognition in the geospatial market, business model design for geo-services, value proposition development, customer discovery, intellectual property strategy). This paper argues that the dominant pedagogical paradigm of passive knowledge transmission, lectures followed by controlled practicals, is fundamentally inadequate for developing this complex, applied, and creative competence profile. Instead, it advocates for the widespread and systematic adoption of **"Learning by Doing" (LbD)** or experiential learning as the central pedagogical philosophy for modern geodesic education. This comprehensive 2000-word

abstract explores the theoretical foundations, practical implementations, and institutional implications of applying experiential approaches to cultivate the digital and entrepreneurial competences essential for the future of the geodesic sciences. It contends that only through immersive, authentic, problem-centered experiences can students construct the integrated, adaptable, and innovative expertise needed to thrive as professionals and entrepreneurs in the digital geospatial era.

Theoretical Foundations: From Knowledge Acquisition to Competence Construction

The argument for experiential learning is grounded in a shift from instructivist to constructivist and socio-constructivist learning theories. **Constructivism,** as advanced by Piaget and others, posits that learners actively construct their own understanding and knowledge of the world through experience and reflection. **Experiential Learning Theory (ELT),** most famously articulated by David Kolb, formalizes this into a cyclical process of concrete experience, reflective observation, abstract conceptualization, and active experimentation. In geodesy, this means moving from being told how a least-squares adjustment works to experiencing the frustration and insight of debugging one's own adjustment code with real, messy GNSS data.

Furthermore, **situated learning theory** (Lave & Wenger) emphasizes that learning is most effective when it occurs within the context and culture of its application—in the "community of practice." For digital and entrepreneurial competences, this context is the authentic, often ill-defined, problem space of professional geospatial work or startup creation. Competence is seen not as a possession but as a situated practice, developed through legitimate peripheral participation in real-world projects. This theoretical framework underscores why simulated classroom exercises fail compared to collaborating on an open-source geospatial tool or conducting user interviews for a proposed geo-app.

Finally, the concept of **entrepreneurial mindset** - a cognitive orientation characterized by opportunity recognition, comfort with ambiguity, calculated risk-taking, and resourcefulness, is understood to be cultivated primarily through action and experience, not theoretical study of business plans.

The Digital and Entrepreneurial Imperative in Geodesy

The nature of required competences has fundamentally expanded:

Advanced Digital Competences: Beyond GIS button-pushing, these now include:

- **Geospatial Data Science & AI/ML**: Building, training, and validating models for spatial prediction (e.g., land use change), image classification (satellite/Drone), and pattern detection.
- **High-Performance & Cloud Geocomputing**: Utilizing parallel processing, containerization (Docker), and cloud platforms (Google Earth Engine, AWS SageMaker) to process continental-scale datasets.
- **Spatial Data Engineering**: Designing robust data pipelines for ingesting, cleaning, transforming, and serving heterogeneous geospatial data streams.
- **Programming & Open-Source Development**: Proficiency in Python, R, JavaScript, and contributions to the open-source geospatial stack (e.g., GDAL, PostGIS, Leaflet).
- **3D/4D Modeling & Digital Twins**: Creating and managing dynamic, semantically rich digital replicas of cities, infrastructure, or natural systems for simulation and analysis.

Entrepreneurial Competences: Critical for translating technical skill into impact and value:

- **Geospatial Market Analysis & Opportunity Recognition**: Identifying unmet needs where spatial intelligence can provide a solution (e.g., precision agriculture, logistics optimization, climate risk insurance).
- **Lean Startup Methodology for Geo-Services**: Developing minimal viable products (MVPs), conducting iterative customer discovery and validation, and pivoting based on feedback.
- **Business Model Design**: Articulating value propositions, revenue streams, cost structures, and customer segments for geospatial products.
- **Intellectual Property (IP) & Data Strategy**: Navigating the complex landscape of open data, proprietary algorithms, and spatial data licensing.
- **Storytelling & Visualization**: Communicating spatial insights compellingly to non-technical stakeholders, investors, and the public.

A Taxonomy of Experiential "Learning by Doing" Approaches in Geodesy

Implementation of LbD can be structured across a spectrum of increasing complexity and authenticity:

1) **Project-Based Learning (PjBL)**: Semester or year-long projects addressing complex, open-ended geospatial challenges. Example: "Develop a multi-criteria site suitability model for renewable energy infrastructure in Region X, using satellite data, socio-economic indicators, and participatory mapping inputs." Students must define the problem, source and integrate data, choose methods, implement solutions (likely coding), and present results, integrating digital and analytical competences.

2) **Problem-Based Learning (PBL)**: Starting with a messy, real-world problem as the catalyst for learning. Example: "The local municipality is experiencing increased urban flooding. Propose a monitoring and mitigation strategy." Students identify knowledge gaps (hydrological modeling, high-resolution DEM analysis, IoT sensor networks) and actively research and apply solutions, driving their own learning agenda.

3) **Case Studies & Simulations**: Using detailed, real-world cases (e.g., the business trajectory of a company like Planet Labs or Esri, or a technical case like managing a national geodetic network modernization). Role-playing simulations, such as a "spatial data startup pitch competition" or a "consultancy bid for a national mapping agency," immerse students in entrepreneurial and professional scenarios.

4) **Internships & Cooperative Education (Co-op)**: The classic experiential model, placing students directly in industry, government, or research labs. To maximize digital/entrepreneurial growth, these must be structured with clear learning objectives, mentor training, and reflective assignments, moving beyond routine technical tasks to innovative project work.

5) **Living Labs & Field-Based Innovation Projects**: Engaging students as co-researchers and co-innovators in real-world test environments. Example: A university partners with a city to create a "Smart City Living Lab." Students deploy IoT environmental sensors, develop dashboards for urban planners, and

analyze mobility patterns, directly experiencing the full cycle of data acquisition, processing, analysis, and application.

6) **University-Based Geospatial Entrepreneurship Programs**:

- **Idea Hackathons & Datathons**: Intensive, short-term events where multidisciplinary teams use provided geospatial datasets (e.g., Copernicus Sentinel data) to prototype solutions to specific themes (e.g., "Ocean Health," "Disaster Response").
- **Geospatial Startup Incubators/Accelerators**: University-run programs that provide mentorship, funding, and workspace for student and alumni teams developing geo-startups. This is the apex of integrated LbD, where technical digital development is constantly pressured and guided by market validation, business model iteration, and investor readiness activities.
- **Capstone Projects with Industry/Community Clients**: Final-year projects sourced directly from external partners with genuine needs. Students act as junior consultants, managing client relations, defining project scope, and delivering a functional tool or analysis, not just a report.

Synergies and Integration: Where Digital Meets Entrepreneurial

The most powerful LbD experiences deliberately fuse digital and entrepreneurial learning. Consider a student team in a geospatial incubator:

- **Digital Competence in Action**: They use Python to scrape and clean urban data, employ Google Earth Engine to analyze historical land cover change, build a machine learning model to predict neighborhood heat island effects, and develop a web-GIS dashboard using JavaScript frameworks to visualize results.
- **Entrepreneurial Competence in Action**: They conduct customer discovery interviews with city planners and insurance companies to validate the problem, iterate their value proposition, develop a freemium business model, create a financial projection, and pitch to a panel of angel investors for seed funding.

This integration ensures that technical prowess is directed by market and societal relevance, and that business ideas are grounded in technically feasible and data-driven solutions.

Overcoming Institutional and Pedagogical Challenges

Implementing this paradigm shift is non-trivial and faces significant barriers:

- **Faculty Development & Incentives**: Many geodesy professors are experts in traditional methodologies, not in cloud AI or lean startup methods. Significant investment in faculty training and creating incentives for innovative teaching (equal to research publication in tenure reviews) is required.
- **Curriculum Rigidity & Siloing**: Packed, rigid curricula leave little room for open-ended, time-intensive projects. Breaking down silos between geodesy, computer science, and business schools to create joint modules or degrees is essential but administratively challenging.
- **Assessment Reformation**: Moving from standardized exams to assessing process, collaboration, creativity, and iterative improvement. Rubrics must evaluate problem-scoping, methodological choices, code quality, reflective practice, and pitch effectiveness.
- **Resource Intensity & Partnerships:** LbD requires more staff time, technological infrastructure (cloud credits, software licenses), and strong, sustained partnerships with industry and community organizations to supply authentic projects and mentorship.
- **Risk and Failure Tolerance**: Experiential learning involves student struggle and potential project "failure." The institutional and classroom culture must shift to view these as valuable learning opportunities rather than negative outcomes.

A Proposed Framework for Implementation

For geodesic science departments, a strategic, phased approach is recommended:

1) **Curriculum Infusion**: Begin by redesigning core courses to include PjBL modules. A "Geodetic Data Analysis" course becomes a project to analyze crustal deformation from a real GNSS network. An "RS & Photogrammetry" course tasks students with creating a digital twin of campus from drone data.

2) **Creation of Integrative Capstones**: Establish a mandatory, year-long capstone where student teams tackle partner-supplied problems, explicitly requiring both a technical solution and a business case or impact assessment.

3) **Development of Ecosystem Partnerships**: Forge formal alliances with geospatial industry partners, startups, government agencies, and NGOs to create a pipeline for internships, project sponsorships, and guest mentorship.

4) **Establishment of a Geospatial Innovation Hub**: Create a physical and virtual center (a "Geo-Innovation Lab") that houses the incubator, hosts hackathons, provides access to advanced computing, and serves as the nexus for experiential activity, bridging academic and entrepreneurial communities.

5) **Adoption of a Reflective Portfolio**: Require students to maintain a digital portfolio (e.g., GitHub for code, website for projects) where they document their projects, reflect on learning, and showcase their integrated competences to employers.

Conclusion: Building the Next Generation of Geospatial Innovators

The future of the geodesic sciences hinges on its ability to produce graduates who are not merely proficient technicians but are geospatial innovators, individuals who can wield advanced digital tools with mastery and deploy them entrepreneurially to create economic, social, and environmental value. The traditional lecture hall is incapable of forging such individuals. It is in the messy, demanding, and exhilarating arena of "Learning by Doing", in the hackathon, the living lab, the startup garage, and the client-facing project, that these essential competences are forged.

By wholeheartedly embracing experiential pedagogies, geodesic education can transform itself. It can move from transmitting a defined body of knowledge to cultivating a dynamic, problem-solving, and opportunity-seeking mindset. This shift will ensure that the field not only keeps pace with the digital revolution but actively leads it, producing a generation of professionals and entrepreneurs equipped to harness spatial intelligence for the sustainable and prosperous development of our world. The mandate is clear: to learn geodesy for the 21st century, students must do geodesy of the 21st century.