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LabEx REPER 3D: Innovative Approaches in Geomatics Education with Low-Cost Solutions

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Abstract

The LabEx REPER 3D at Université Laval is dedicated to advancing education, research, and innovation in geomatics by integrating low-cost technologies. Recognizing the need for affordable and practical training tools, REPER 3D leverages accessible platforms—including aerial drones, imaging sensors, miniature autonomous vehicles, and Autonomous Surface Vehicles (ASVs)—to simulate real-world geospatial applications in controlled settings. These initiatives bridge the gap between theoretical knowledge and hands-on expertise, empowering students to engage with mobile mapping, photogrammetry, and hydrospatial techniques. Furthermore, REPER 3D prioritizes Open Educational Resources (OER) by developing reproducible and accessible methodologies, fostering interdisciplinary collaboration, and contributing to the democratization of geomatics education. By emphasizing affordability, replicability, and knowledge-sharing, REPER 3D advances equitable access to geospatial education, reinforcing its role as a catalyst for innovation in the field.

1 - Introduction

While advanced technologies have become more affordable in the past decade, access to practical geospatial education that integrates these technologies remains a challenge for practitioners across the globe. Indeed, if Open Educational Resources (OER) have contributed to making theoretical knowledge in geomatics broadly available in recent years, resources and tools oriented towards practical learning in geomatics are still limited.

International frameworks such as the UNESCO Recommendation on OER (2019) and the Dubai Declaration (2024), however, emphasize the need to go beyond content availability and ensure equitable access to the tools and infrastructure necessary for meaningful engagement with emerging technologies, including geomatics.

The Experiential Laboratory in 3D Representation and Perception (LabEx REPER 3D) at Université Laval directly addresses this gap by fostering innovation at the intersection of geomatics and open education. The lab focuses on developing and using low-cost, customizable technologies—such as aerial drones, imaging sensors, miniature autonomous vehicles, and Autonomous Surface Vehicles (ASVs)—to create hands-on environments and tools for learning geomatics in controlled indoor spaces. Hence students can engage with these technologies in controlled but real-world-like simulation scenarios, acquiring essential skills in mobile mapping, photogrammetry, and hydrospatial.

REPER 3D's commitment to open education is reflected in its emphasis on knowledge sharing, interdisciplinary collaboration, and the development of open source reproducible and accessible technologies and pedagogical tools. This paper presents two key activities led by the REPER 3D team that demonstrate how open education can be advanced through low-cost technological innovation in geomatics. By focusing on affordability, replicability, and adaptability, these projects aim to empower students and communities worldwide to engage meaningfully with spatial and hydrospatial data, ultimately contributing to a more equitable and resilient future. The paper is structured as follows: in the next section, we provide an overview of the REPER 3D laboratory and its academic context. The following sections present two OER-focused activities led by the REPER 3D team in the fields of hydrospatial and photogrammetry. A subsequent section will synthesize and discuss the broader challenges involved in creating OER for geomatics education. Finally, the paper concludes with some perspectives for the future.

2 - REPER 3D Laboratory

2.1 - Context and Origins

The field of geomatics is undergoing a profound transformation, driven by the democratization of sensors, data acquisition platforms, and digital tools. The rapid evolution of technology has made cutting-edge instruments—once prohibitively expensive—more accessible, lowering financial barriers that traditionally hindered engagement with geomatics (Manfreda et al. 2018). This shift is particularly significant in education, where students and instructors now have unprecedented opportunities to engage with advanced tools and methodologies. However, despite this progress, many challenges remain to have access to education material based on theses technologies and to bridge the gap between education context and real-life scenarios. In response to these challenges, REPER 3D was established at Université Laval in 2023 (Figure 1). Bringing together a multidisciplinary team of professors, researchers, specialists, and students from fields such as geomatics, engineering, and computer science, REPER 3D seeks to explore innovative approaches to geomatics education and research. The laboratory mission is twofold: to provide open, high-quality training based on affordable equipment and to develop low-cost solutions that reduce economic barriers to entry in the field. Through its activities, REPER 3D aims to empower students, educators and professionals by fostering a culture of openness, accessibility, and technological inclusion.

Figure 1 – The environment of the REPER 3D laboratory

2.2 - REPER 3D Objectives

The work developed in REPER 3D aligns closely with the principles of Open Education, emphasizing accessibility, collaboration, and knowledge democratization. Its activities focus on five key objectives:

1. Developing Experience-Based Training.

REPER 3D designs and implements hands-on, hybrid training programs that enable students to engage with real-world case studies in geomatics engineering and surveying. These activities bridge the gap between theoretical knowledge and practical application, reinforcing experiential learning.

2. Simulating Real-World Data Acquisition.

To ensure students gain practical expertise, the lab develops field-based exercises that replicate professional geomatics situations. Emphasizing open-source tools and affordable technologies, these activities allow learners to acquire industry-relevant skills without reliance on costly proprietary systems.

3. Enhancing Research Capabilities.

With a controlled yet realistic simulation environment, REPER 3D explores 3D perception and representation of physical environments, providing an open, replicable framework for geomatics studies. By making methodologies, datasets, and findings publicly accessible, REPER 3D contributes to open education and to collaborative, transparent research, fostering a global exchange of knowledge.

4. Promoting Student-Led Innovation.

Beyond knowledge consumption, REPER 3D encourages students to create their own open educational resources. This process nurtures innovation through problem-solving skills, independent learning, and a mindset of openness, ensuring that future professionals contribute to expanding accessible geomatics solutions.

5. Strengthening Collaboration.

Recognizing the importance of community-driven learning, the lab fosters connections between students, faculty, researchers, and industries. Through partnerships with academic and professional networks, REPER 3D facilitates cross-institutional collaborations and knowledge sharing, reinforcing the global open education movement in geomatics.

2.3 - Support and Community

The increasing significance of OER in higher education is widely acknowledged for their potential to broaden and democratize access to knowledge and scientific learning (Hewlett Foundation 2025). In Canada, associations such as the Canadian Association of University Teachers (CAUT) and the Canadian Digital Learning Research Association (CDLRA) actively support the adoption of OER, by developing programs that equip educators, among which the REPER 3D team, with skills to create and integrate OER into their own teaching. Thanks to this community, our team gains support regarding open licensing, copyright considerations, and pedagogical design of open materials. Also, REPER 3D team is actively engaged in the broader geomatics education community. The lab takes part to the Canadian Ocean Mapping Research and Education Network (COMREN), contributing to national efforts in hydrography education and research. Additionally, REPER 3D collaborates with the Surveying and Geomatics Educators Society (SaGES), participating in discussions and initiatives aimed at improving geomatics education through open and innovative teaching practices.

Low-cost platforms and sensors play a crucial role in advancing accessible education and research in geomatics. REPER 3D is engaged in supporting Duckietown community, an open-source educational robotics initiative that exemplifies collaborative, hands-on learning in spatial technologies and intelligent systems. Duckietown provides a scalable and modular framework supported by a global network of contributors, offering open-source hardware, software, and simulation tools well-suited for academic settings. This ecosystem aligns with REPER 3D's mission by facilitating experimentation, interdisciplinary training, and integration of robotics, artificial intelligence, and applied geomatics. The availability of community support, comprehensive documentation, and global events further strengthens its impact in educational contexts (Duckietown 2025a; 2025b). In addition to Duckietown, REPER 3D leverages other open and affordable platforms such as Raspberry Pi, Jetson Nano, and the OAK-D depth camera. These tools enable the development of customizable, low-cost sensing and computing systems for geomatics applications. Their open-source nature and compatibility with a wide range of sensors make them ideal for teaching and prototyping in environments constrained by budget or infrastructure, fostering inclusive and innovative learning experiences in the geomatics domain.

3 - REPER 3D Activities in Hydrospatial

Hydrospatial can be defined as the seamless integration of marine, coastal, and inland water data into a framework. It supports enhanced decision-making, innovation, and sustainable development across the Blue Economy by connecting hydrography, oceanography, and geospatial intelligence to better understand, manage, and protect aquatic environments and related resources (adapted from Hains et al. 2021).

In recent years, OER have emerged as valuable tools for supporting hydrospatial education and training (IHO eLearning 2025; GEBCO training program 2025). However, existing OER in hydrospatial predominantly focus on software platforms, publicly available datasets, and theoretical frameworks, with limited emphasis on accessible, low-cost tools for practical learning. Addressing this limitation, the development and dissemination of affordable hydrographic survey tools present a meaningful opportunity to expand the reach and practical impact of hydrospatial education.

3.1 - Development of a Low-Cost Bathymetric ASV

The development of low-cost ASVs is not new in the hydrospatial context. Various authors have built relatively affordable ASVs (Giordano et al. 2015; Caccia et al. 2007), but the central challenge in these projects mainly lied in the physical and geometric integration of sensors and their synchronization—an aspect well discussed in the literature (Jung et al. 2021; Giordano et al. 2015; Hassan et al. 2012). However, the value of a low-cost bathymetric drone extends beyond sensor integration. It requires thoughtful design choices and documentation to ensure its user-friendliness, practical usability and adoption. Hence, the REPER 3D team is involved in developing a low-cost bathymetric ASV (Hascoët et al. 2024) that can be effectively promoted and replicated with limited resources for different uses and contexts, including for education. Unlike traditional hydrographic vessels, which rely on expensive high-end equipment and are costly to maintain, this ASV uses affordable components while maintaining the precision needed for underwater mapping and depth measurements in coastal areas. It also integrates user-oriented considerations regarding power supply, robustness, and ergonomics with the goal of democratizing hydrography among local communities by providing a practical, hands-on solution for learning and research.

The ASV is equipped with essential, reliable tools, including a single-beam echo sounder, a positioning system, and a digital depth recorder, enabling effective bathymetric data collection. Its design ensures stable movement across various water surfaces, such as rivers, lakes, and shallow coastal areas, offering versatility for diverse environments. A key feature of the ASV is the Raspberry Pi, a low-cost flexible microcomputer, serving as the central processing unit for the open-source software system. Its small size, computational power, and compatibility with numerous sensors make it ideal for managing real-time data acquisition, processing bathymetric data, and interfacing with navigation and echo sounder equipment. The Raspberry Pi's support for multiple programming languages and software libraries enhances its adaptability for global users. The modular design of the ASV allows easy integration of advanced sensors, ensuring its evolution with technological advancements.

Powered by standard, rechargeable power tools batteries, the ASV minimizes operational costs and environmental impact while offering extended fieldwork capabilities, even in remote or off-grid areas. It also relies on two boat hulls (forming the catamaran) that are easily accessible, robust and replaceable. With a weight under 15 kg, it is easy to manipulate by one person and it is equipped with handles to make it easy to put in the water. The ASV comes with a step-by-step documentation and material parts list, that will be available online on the REPER 3D website. Figure 2 illustrates the ASV developed by REPER 3D.

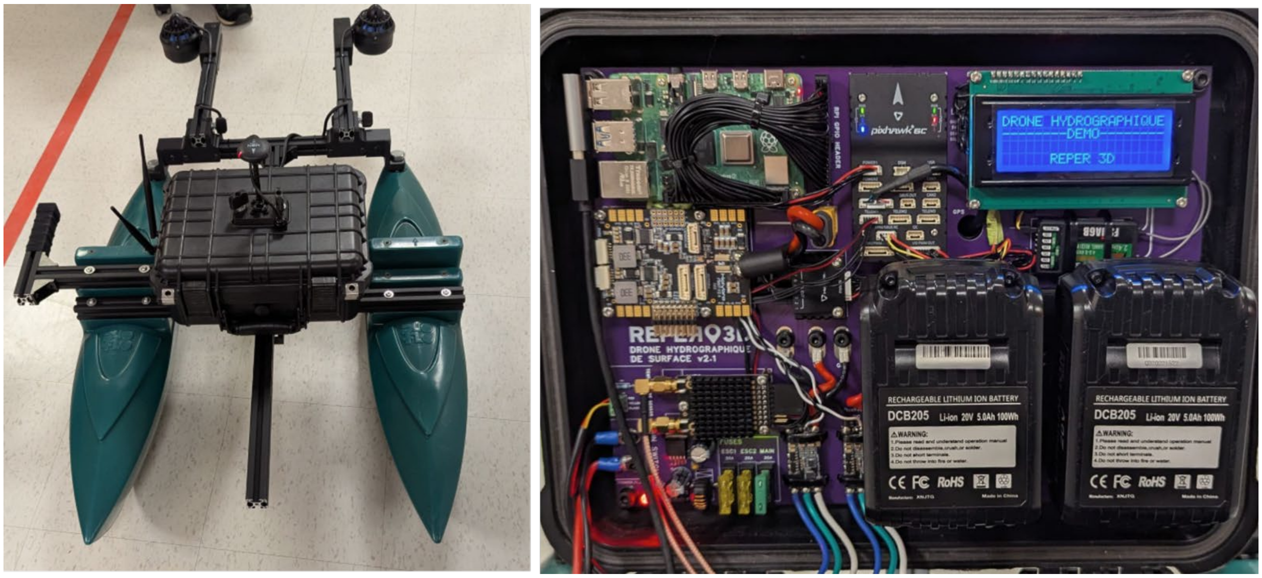

Figure 2 - ASV developed by REPER 3D

The REPER 3D ASV uses open-source hardware and software, such as the Raspberry Pi, to enable flexible sensor integration and data processing. While these technologies help reduce costs and provide extensive documentation, they do introduce some complexities in software development that require familiarity with Python and ROS (Robot Operating System 2025). However, this is not a significant limitation thanks to the large and active community surrounding these tools, which offers abundant resources, tutorials, and support. Nonetheless, users should expect to invest a certain level of effort to fully leverage these technologies and ensure seamless operation. Ensuring real-time synchronization between the echosounder and the positioning system (GNSS – Global Navigation Satellite System and IMU – Inertial Measurement Unit) is essential for accurate bathymetric readings. Fortunately, the REPER 3D team benefits from a diverse range of expertise to tackle these challenges.

A distinctive feature of low-cost hydrospatial platforms like ASVs in OER initiatives is their open-source nature, encompassing both hardware and software components. This openness empowers users to modify and tailor systems to local contexts, fostering innovation and building a global community of practitioners who share improvements and knowledge. Comprehensive guides, including step-by-step instructions and code samples, lower technical barriers, making the technology accessible to users with limited expertise. For instance, the REPER 3D ASV project exemplifies this approach by utilizing affordable yet reliable hardware. While these choices introduce challenges in depth resolution, accuracy, and real-time positioning, ongoing efforts to integrate sensors effectively and validate data quality aim to meet diverse project requirements. By improving power management and overcoming technical constraints, such open-source platforms advance hydrographic surveying and promote long-term sustainability, collaboration, and customization in hydrography education. Additionally, multilingual educational materials and interactive resources are being developed to enhance accessibility and align with the principles of OER.

3.2 - Challenges of Low-Cost Hydrospatial in Education

The example of the ASV demonstrates that it is possible to design and implement low-cost tools to support hydrospatial experiential education. However, hydrospatial education faces more restricted access to sensors and platforms compared to disciplines like photogrammetry or related domains. Although OER are increasingly accessible, significant challenges remain. A primary issue lies in the availability of standardized workflows and acquired data. Existing standards tend to focus on high-end instrumentation and are often unsuitable for the constraints and characteristics of affordable systems such as small ASVs or low-cost sonar platforms. Ensuring reproducible and reliable results with these systems requires well-documented procedures and targeted training resources—gaps that current OER initiatives seek to address through comprehensive, adaptable methodologies.

Another major challenge concerns the interoperability and compatibility of open-source software commonly used in geospatial applications. These tools often vary in supported data formats, sensor interfaces, and processing capabilities, creating technical barriers for users who must frequently convert or preprocess data to ensure cross-platform compatibility. Inconsistencies in metadata standards and coordinate reference systems further contribute to errors and inefficiencies in data analysis and visualization. Consequently, educators and students encounter steep learning curves that hinder the adoption of seamless, end-to-end workflows essential for effective hydrospatial education and its practical application.

Finally, concerns around the free online sharing of hydrospatial data include privacy and ethical considerations, particularly when georeferenced data capture sensitive coastal or marine environments, protected areas, or private properties. Addressing these issues necessitates careful data anonymization and adherence to legal frameworks, all while preserving the educational value of open data resources.

4 - REPER 3D Activities in Photogrammetry

Photogrammetry is the science of obtaining reliable information about physical objects and the environment through the process of acquiring, processing, measuring, and interpreting images (Wolf and Dewitt 2000). It is a key tool in different fields such as geography, engineering, architecture, urban planning, and environmental monitoring. Photogrammetric approaches allow the production of accurate 3D models from 2D imagery. Recently, the rise of low-cost drones and open-source software has increased accessibility to photogrammetry. However, teaching photogrammetry with such tools presents a few challenges. These may include limitations in image resolution, sensor accuracy, and software processing capabilities, which can reduce the precision and reliability of outputs (Turner et al. 2012; Colomina and Molina 2014). Despite these constraints, the open-source software has a highly engaged online community providing mutual support. In this context, low-cost photogrammetry remains a valuable educational tool for teaching spatial analysis and 3D modeling. Taking part to this collective effort, the REPER 3D team develops methods using entry-level drones, lowering both financial and technical barriers in education.

4.1- Photogrammetry in Miniature and Real Urban Areas

4.1.1 - Acquisition and Processing of Photogrammetric Data Indoors

REPER 3D has developed an indoor miniature urban area that offers several advantages for teaching photogrammetry, including controlled environments for consistent data acquisition, reduced weather dependency, and cost-effective learning opportunities. It enables hands-on experience with real-world scenarios, allows for easy testing of various sensors and techniques, and enhances the understanding of spatial data applications. In this context, hands-on activities have been developed for students to plan, acquire and process photogrammetric imagery data as well as static terrestrial LiDAR data. As part of this activity, the students can pilot a drone over the miniature urban environment to acquire birdeye imagery. The use of a drone weighing less than 250g eliminates the need for a pilot's certificate. The photogrammetric data acquired during these activities can be processed using both proprietary and open-source software solutions. In this same context, the use of Duckiebots can reproduce the data acquisition of a mobile mapping system through the miniaturized urban environment of REPER 3D. These acquisition systems are illustrated in Figure 3.

Figure 3 - DJI Neo mission over REPER 3D town with a Duckiebot.

New hands-on exercises dedicated to three essential steps in image processing have also been created and will be publicly available soon at REPER 3D website (https://reper3d.ffgg.ulaval.ca/publications). First, camera calibration is performed using a checkerboard (see on the right end side of Figure 1). This process can be applied to a variety of cameras (e.g. drones, mobile robots called Duckiebots, smart cameras OAK-D). Next, image rectification and georeferencing use known targets strategically placed within the miniature urban environment. Finally, mosaicking is carried out by stitching together the rectified images to create a seamless and continuous representation of the studied area (Figure 4). Students have access to Jupyter notebooks, within which these steps are programmed in Python, making the underlying theoretical and mathematical concepts explicit.

Figure 4 - Orthoimage of REPER 3D town.

Using Duckiebots (Tani et al. 2017) over REPER 3D town, different academic activities are in development to simulate real-time mobile mapping solutions using miniature autonomous vehicles. Among the solutions developed, some allow the Duckiebots to recognize specific locations, such as traffic signs and house facades (Figure 5). The project also includes cameras equipped with artificial intelligence processors (OAK-D), used in both static and dynamic modes, providing complementary viewpoints to those of the Duckiebots. This context is ideal for developing 3D reconstruction solutions for objects present on the model. In static mode, shape recognition methods—leveraging digital vision along with machine and deep learning techniques—are applied to images captured by the OAK-D camera to visually relocate, map, and identify landmarks within the environment. In dynamic mode, the project simulates aerial overflight configurations using OAK-D cameras in a controlled setup, where all sensor position and orientation data are known. Since the model is georeferenced, it becomes possible to track the real-time trajectory of the Duckiebots through photogrammetric methods. A key educational dimension of this work is its alignment with OER principles: all components are open source, including the Duckiebot hardware, Python code (existing and newly developed), deep neural network models, and the tools used to build training datasets. While code publication is not a formal objective of the current phase, the open-source foundation ensures that these materials can be shared and reused. Additionally, datasets generated through these activities may be made available to support other groups in simulation, algorithm testing, or educational exploration—further reinforcing the project's contribution to accessible and collaborative learning.

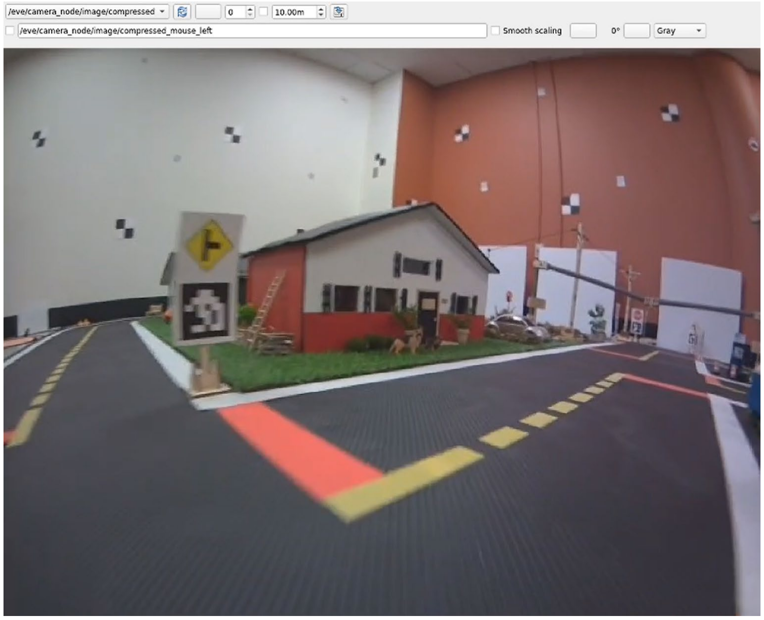

Figure 5 – A view of the miniature urban environment from the Duckiebot fisheye camera.

4.1.2 - Use of Low-Cost Drones in Real Urban Context

In addition to educational activities, research projects are conducted by the REPER 3D team. One of them (Laplante et al. 2024) has consisted in evaluating the quality of photogrammetric products (i.e. pointclouds and orthophotos) acquired using three drones: the Autel EVO II Pro (low-cost), the DJI Mavic 3E (mid-range), and Microdrones mdMapper 1000 DG (high-end). Surprisingly, the DJI Mavic 3E provided spatial accuracy similar to the mdMapper 1000 DG, despite differences in hardware specifications. The EVO II Pro, while inducing slightly more noise in the final products, also delivered results within acceptable accuracy thresholds defined by the American Society for Photogrammetry and Remote Sensing (ASPRS) that acts as a standardisation organism in the field of photogrammetry. The analysis confirmed that noise in low-cost drone outputs can often be reduced in post-processing, while the visual rendering quality—especially with double-grid flight patterns—was often higher in the EVO II Pro and Mavic 3E outputs compared to the high-end system.

The project final point clouds and orthophotos will be made available online. Figure 6 provides an example of such dataset. These data will soon be published in the data repository of Université Laval, providing open access for researchers and students.

Figure 6 – 3D model of the Louis-Jacques Casault Hall built using photogrammetric data (left QR code leading to online orthoimages of ULaval campus; right QR code leading to ULaval point cloud acquired by Mavic 3 Enterprise).

REPER 3D efforts to develop OER includes open-access documentation of workflows, video tutorials, and processing guidelines using open-source tools such as WebODM (OpenDroneMap 2025), CloudCompare (CloudCompare 2025) and QGIS (2025). These materials help instructors and students replicate high-quality results using cost-effective technologies. The initiative also emphasizes standard compliance, referencing the ASPRS (2024) guidelines for accuracy and control point distribution, ensuring that learners are not only using accessible tools but also adhering to professional best practices. This study demonstrates the viability of integrating low-cost drone technologies into OER frameworks for photogrammetry. By providing open methodologies, tools, and training materials based on accessible hardware, REPER 3D enhances the potential for hands-on geospatial education in universities and technical programs globally. Ultimately, REPER 3D contributes to the ongoing shift toward inclusive, practical, and scalable photogrammetry training.

4.2- Challenges of Low-Cost Photogrammetry for Education

The first challenge addressed by the OER from REPER 3D consists in the availability of standardized workflows. Despite the increasing availability of OER, there is still a need for universally adopted standards in low-cost drone photogrammetry. ASPRS (2024) has issued the standards for surveys, data processing and photogrammetric products. However, they are still based on airborne photogrammetry and are not well adapted to drone-based photogrammetry, especially low-cost drones. Ensuring consistent results with low-cost systems requires well-documented procedures and training materials, a gap that REPER 3D intent to close through its comprehensive methodology.

Another challenge is related to the use of open-source software, which provides affordable solutions. However, it often comes with compatibility issues. Integrating different drones with various software tools (e.g. WebODM, UASMaster, and CloudCompare) can create technical barriers for users unfamiliar with the platforms. Moreover, low-cost drones may not be fully compatible with certain high-performance software packages, limiting the tools available for analysis and visualization. This creates additional challenges in ensuring smooth workflows and consistency when using diverse equipment.

A more significant challenge is related to free online diffusion of data, involving data privacy and ethical concerns. While making photogrammetric data publicly available through OER promotes transparency and accessibility, it can raise concerns when it comes to sensitive or private information contained in the collected imagery. In urban environments, for example, georeferenced data might inadvertently capture private properties, identifiable individuals, or confidential infrastructure. Ensuring that the data shared online complies with ethical standards and privacy regulations is a significant challenge. This requires careful data anonymization and metadata handling to ensure that no sensitive information is exposed while still providing valuable educational resources. In the context of citizen science, this challenge is compounded by inconsistent metadata practices. Contributed datasets often lack essential contextual information—such as acquisition conditions, sensor specifications, or contributor identity—making it difficult to assess their reliability or distinguish them from professionally collected datasets. Clear metadata protocols are therefore essential to maintain transparency, traceability, and educational value. In the case of REPER 3D projects, the use of campus imagery provides a practical advantage: it offers a representative urban dataset while minimizing privacy concerns typically associated with public space imaging. This controlled environment enables the generation of high-quality, georeferenced datasets that are both ethically sound and pedagogically rich, supporting the open dissemination of data without compromising individual privacy.

5 - Discussion

This paper presents initiatives that address the barrier of access to affordable geomatics education tools. By developing or using low-cost technologies in hydrography and photogrammetry, REPER 3D contributes to the OER movement, offering practical, accessible, and adaptable solutions. By documenting and sharing technical designs, methodologies and datasets, these initiatives enhance the availability of high-quality OER in a field that is often dominated by expensive and proprietary technologies. REPER 3D efforts to work with consumer-grade hardware, open-source software, and experiential learning models directly support broader goals set forth in international declarations such as the Dubai Declaration on OER and the United Nations Sustainable Development Goals, notably SDG 4 on inclusive and equitable quality education.

Despite their potential, the proposed low-cost solutions raise several questions about their global applicability and long-term viability. What is considered "low-cost" in a Canadian context may still represent a significant investment elsewhere. While drones and components used in these projects are affordable compared to industrial systems, their cost, maintenance requirements, and technical support may remain out of reach for institutions in lower-income regions. Moreover, many of the systems used rely on components manufactured overseas. This dependence raises environmental and ethical concerns related to production, transportation, and supply chain sustainability. These issues must be considered when evaluating the overall ecological footprint of so-called low-cost technologies.

Despite these limitations, the REPER 3D initiatives show strong potential for transforming the way geomatics is taught and learned. By promoting the use of low-cost equipment and allowing active, hands-on experience, the OER developed by REPER 3D offer a powerful complement to traditional geomatics instruction and to existing OER that mainly focus on software and teaching resources. The open and adaptable nature of the resources developed enables institutions to build local expertise and innovate within their own teaching contexts. Furthermore, these projects create opportunities for interdisciplinary collaboration—between engineering, geography, education, and computer science—and promote a culture of sharing and co-creation. In doing so, they strengthen not only technical skills but also critical thinking, problem-solving, and the collective capacity to respond to environmental and societal challenges using geospatial tools.

6 - Conclusion

This paper presents a series of initiatives developed by the REPER 3D laboratory at Université Laval to support the integration of low-cost technologies into Open Educational Resources (OER) for geomatics sciences. Through projects in hydrography and photogrammetry, the lab seeks to reduce the financial, technical, and pedagogical barriers that currently limit access to geospatial training tools.

By combining hands-on experimentation with open-source software and commercially available hardware, the REPER 3D team demonstrates that high-quality geomatics education can be achieved without relying on expensive proprietary systems. These initiatives not only enrich the OER ecosystem with practical and transferable content but also contribute to broader goals in sustainable development and inclusive education.

However, the work presented here also reveals some limitations and challenges—economic, environmental, cultural, and technical—which must be addressed to ensure true global accessibility. The notion of “low-cost” should be critically examined in diverse geopolitical contexts and greater efforts must be made to adapt educational tools to local needs, languages, infrastructures and sustainability goals

Moving forward, REPER 3D will continue to refine its methodologies, expand its collaborations, and explore the integration of emerging technologies such as artificial intelligence to further personalize and contextualize learning. These ongoing efforts reinforce the idea that openness in education is not only about access to content, but also about enabling learners—wherever they are—to engage meaningfully, experiment boldly, and contribute creatively to knowledge-building within their own contexts.

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