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Examining European student geographic mobility in the space field: ASTRAIOS project insight

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Abstract

This paper is an analysis of European student mobility within the space sector through a statistical analysis as part of ASTRAIOS project. The results show that there are considerable variations in geographical participation, with Western Europe being the most dominant. Barriers such as language, economic factors, and lack of industry-academia collaboration are identified. Standardising space-related courses, increasing financial support, and soft skills training are some strategic ideas. If the recommendations are considered, existing educational gaps can be addressed, also the mismatch between graduates and the workforce requirements can be reduced to enhance Europe's competitive standing in the global space industry.

1. Introduction

Student mobility, defined as the movement of students internationally for educational purposes, has become integral to global higher education. This mobility enhances cross-cultural competencies, global citizenship, career prospects, and significantly contributes to academic, personal, and professional development [1,2]. International student mobility is recognised as crucial in responding to the demands of an increasingly globalised economy, enhancing intercultural competencies, language proficiency, and employability [2]. However, despite the clear benefits, global student mobility encounters persistent barriers such as economic constraints, language differences, institutional incompatibilities, and socio-cultural challenges [3]. Recent global events, notably the COVID-19 pandemic, have further reshaped international mobility patterns, highlighting vulnerabilities and adaptability within educational systems [4-10].

In Europe, student mobility has been strongly promoted through structured initiatives, most notably the Erasmus+ program, designed to facilitate cross-border educational exchanges, internships, and professional training [4]. Erasmus+ has enabled millions of European students to gain intercultural experiences and professional skills critical to their career development. Despite this, significant disparities remain in participation rates across European nations, reflecting underlying economic and institutional differences [5]. Recent studies underline how Erasmus+ experiences substantially enhance cultural competencies and career prospects, with measurable benefits extending beyond mere academic achievement [6]. Nevertheless, Europe's mobility landscape remains partially stratified, as Western European nations attract disproportionately higher student flows compared to Eastern and Southern European countries, exacerbating geographical inequalities [7,8,10].

In the specific context of the space sector, education plays a pivotal role in addressing workforce shortages and aligning academic training with industry needs. Europe's rapidly growing space sector is marked by technological innovation and increased strategic investments, requiring a highly skilled and versatile workforce adept in areas like space systems engineering, data analytics, satellite communications, and artificial intelligence-driven testing methods [7,8,10]. Yet, specialised educational programs within the space sector are disproportionately concentrated in a few countries, primarily France, Germany, Italy, and the United Kingdom, thereby deepening regional disparities across the continent. This uneven distribution of educational resources results in regional skill shortages, promoting brain drain from Eastern and Southern European regions toward established educational and industrial hubs in the West [9,10].

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Despite the recognised importance of mobility in addressing these workforce gaps, detailed analyses specifically targeting student mobility within space education remain relatively limited. Research indicates only around 7% of European universities offer dedicated space-related curricula, reflecting structural barriers within the educational system itself, such as limited standardised curricula, insufficient cross-border recognition of qualifications, and minimal dual-degree programs [9,11]. Additionally, recent analyses emphasise that beyond technical expertise, space professionals require substantial soft skills such as intercultural communication, adaptability, problem-solving, and digital fluency—skills currently underrepresented in existing curricula [13].

Recognising these critical gaps, the ASTRAIOS project—funded as a Horizon Europe Coordination and Support Action (CSA)—was launched in January 2023. ASTRAIOS aims to comprehensively map space education offerings, forecast future workforce demands, and identify skill gaps across Europe [12,13]. Leveraging advanced analytical methodologies, including natural language processing (NLP), fuzzy logic matching, and big data analytics applied to mobility data from 2013 to 2023, ASTRAIOS provides robust insights into geographic disparities and mobility patterns in European space education [10]. Through detailed demographic and educational analyses, ASTRAIOS seeks to inform strategic policy recommendations and interventions designed to mitigate geographical inequalities, enhance international student mobility, and better align education with space sector needs.

The Horizon Europe-funded ASTRAIOS (Analysis of Skills, Training, Research and Innovation Opportunities in Space) project (36 months (2023–2025)) is a multi-partner initiative to map and analyse space-related education in Europe. The current paper extends the insights provided by ASTRAIOS and existing literature, offering an in-depth examination of student mobility trends, geographical disparities, and demographic factors within European space education. By analysing Erasmus+ mobility data over the past decade, this study identifies structural challenges and proposes targeted recommendations, aiming to foster equitable skill distribution, improve educational alignment with industry requirements, and sustain Europe's global leadership in the rapidly evolving space sector.

2. Methodology

The methodological framework adopted in this paper builds upon comprehensive analytical approaches developed within the ASTRAIOS project, employing both quantitative and qualitative techniques to address the complexity of geographic student mobility in European space-related education. A multi-stage analytical process was followed, leveraging data collected from various sources, including Erasmus+ mobility data (covering academic years 2013-2023), the ASTRAIOS educational database, surveys, and LinkedIn Talent Insights analyses.

Initially, a detailed dataset from the Erasmus+ mobility program was utilised as the foundational data source. This dataset comprises mobility data for approximately 5.9 million students, participating across 28 European countries, with additional categorisation for participants from non-EU countries. Raw data underwent rigorous pre-processing steps, including standardisation, error correction, and normalisation to ensure data consistency and reliability. Participant counts were expanded into individual-level records to enable fine-grained analyses [10].

Subsequently, advanced data analysis methodologies were employed, particularly focused on capturing the nuanced trends of student mobility. Natural Language Processing (NLP) techniques were applied to analyse curriculum descriptions and course documentation available in the structured ASTRAIOS database, specifically curated to map higher education institutions (HEIs) offering space-related courses across the EU-27 and the UK [9,10]. NLP techniques facilitated automated categorization of space-relevant educational programs and allowed the identification of curricular and thematic trends influencing student mobility.

To further enrich the analysis, fuzzy logic matching and API-driven validation techniques were utilized to integrate and verify data obtained from diverse sources, including LinkedIn Talent Insights. These techniques were crucial in ensuring robust matching and validation of demographic, institutional, and curricular data sets, thus significantly enhancing the accuracy and representativeness of the findings [6,10].

Triangulation of findings was conducted by integrating three data streams (Figure 1):

(1) Erasmus+ participant mobility flows (individual-level data derived from expansion of 'Actual Participants'),

(2) Survey responses students and educators collected during project activities in 2 years,

(3) LinkedIn Talent Insights covering 170,000+ space professionals across 1,800 organizations.

This triangulated methodology ensured alignment across qualitative, demographic, and labour market perspectives, increasing the reliability of the insights presented.

A substantial component of this methodology was dedicated to visualisation and exploratory data analysis. Sankey diagrams were developed to effectively illustrate and interpret complex student mobility patterns, clearly demonstrating directional flows, source and destination countries, as well as changes across academic years. Additional visual analytics included grid plots to map and identify specific temporal trends and regional disparities across Europe [10].

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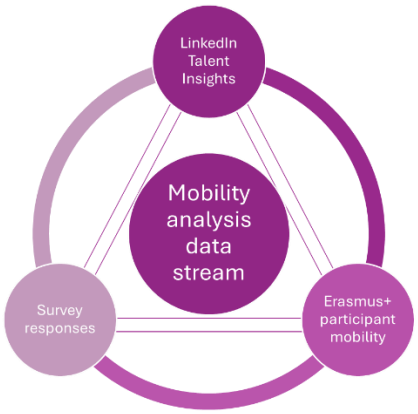

Figure 1: Triangulated data integration process used in the ASTRAIOS analysis.

Further qualitative insights were obtained from targeted surveys conducted among students and professionals engaged in space education. These surveys, implemented through both online platforms and direct distribution at space-related academic and industry events, provided valuable data on mobility motivations, barriers, experiences, and perceptions regarding career and educational trajectories. Responses were statistically analysed to identify key influencing factors in mobility decisions, such as curriculum attractiveness, economic considerations, and cultural factors, as well as to assess the prevalence of soft skills development within these mobility experiences [11,13].

Moreover, LinkedIn Talent Insights were employed to extract complementary demographic and occupational mobility data. This allowed a deeper analysis of career transitions, skills demand, workforce distribution, and correlations between academic mobility and subsequent professional career movements within the space sector [10,13].

The combination of these approaches has provided a robust analytical base, facilitating comprehensive insights into the European space education landscape and enabling robust policy recommendations. In particular, these integrated methodologies highlighted structural gaps, demographic disparities, and mobility trends that are critical for future strategic policy-making and educational planning within the rapidly evolving European space industry.

3. Results and Analysis

The analysis conducted in this study generated key insights into European student mobility within the space field, revealing significant geographical disparities and crucial trends that highlight the existing gaps within space-related educational offerings across Europe.

3.1 Mobility Trends Across Academic Years

The detailed analysis of Erasmus+ mobility data from 2013 to 2023 (expanded to ~5.9 million individual records) reveals year-on-year fluctuations influenced by major global events. Following a drop during the COVID-19 pandemic (2019–2021), As illustrated in Figure 2, participation rebounded strongly in 2021–2022 with over 1.2million participants, highlighting both the system's resilience and the continued demand for international academic experiences.

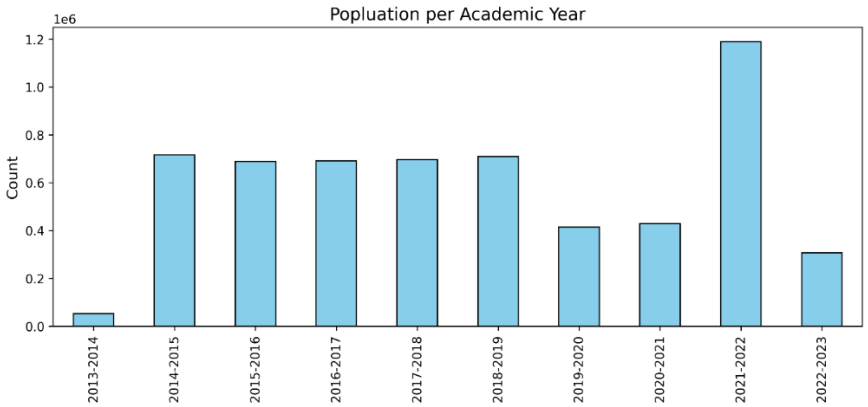

Figure 2: Population Trends Across Academic Years

DOI: 10.13009/EUCASS2025-765

3.2 Geographical Patterns and Disparities

Geographical analysis indicates substantial disparities between source and destination countries in terms of student mobility flows within Europe. Western European nations—particularly Spain, Germany, and France—emerged as the dominant destination countries, consistently receiving the highest number of Erasmus+ students across the analysed decade. These trends are illustrated in Figure 3.

This spatial imbalance highlights Western Europe's position as a magnet for academic talent and mobility, potentially exacerbating economic and knowledge inequalities across the continent. In contrast, countries in Eastern and Southern Europe such as Romania, Bulgaria, and Croatia received relatively low numbers of incoming students, typically remaining below 2% annually over the past ten years. These findings explain more in [10], which documented the correlation between low inbound mobility and limited access to specialised, internationally-oriented curricula—especially in space-related disciplines.

Figure 3 also includes a category labelled "Other," which refers to mobility flows involving countries outside the EU-27 and the United Kingdom. These cases fall outside the primary geographical scope of the ASTRAIOS project but are still registered under Erasmus+ statistics.

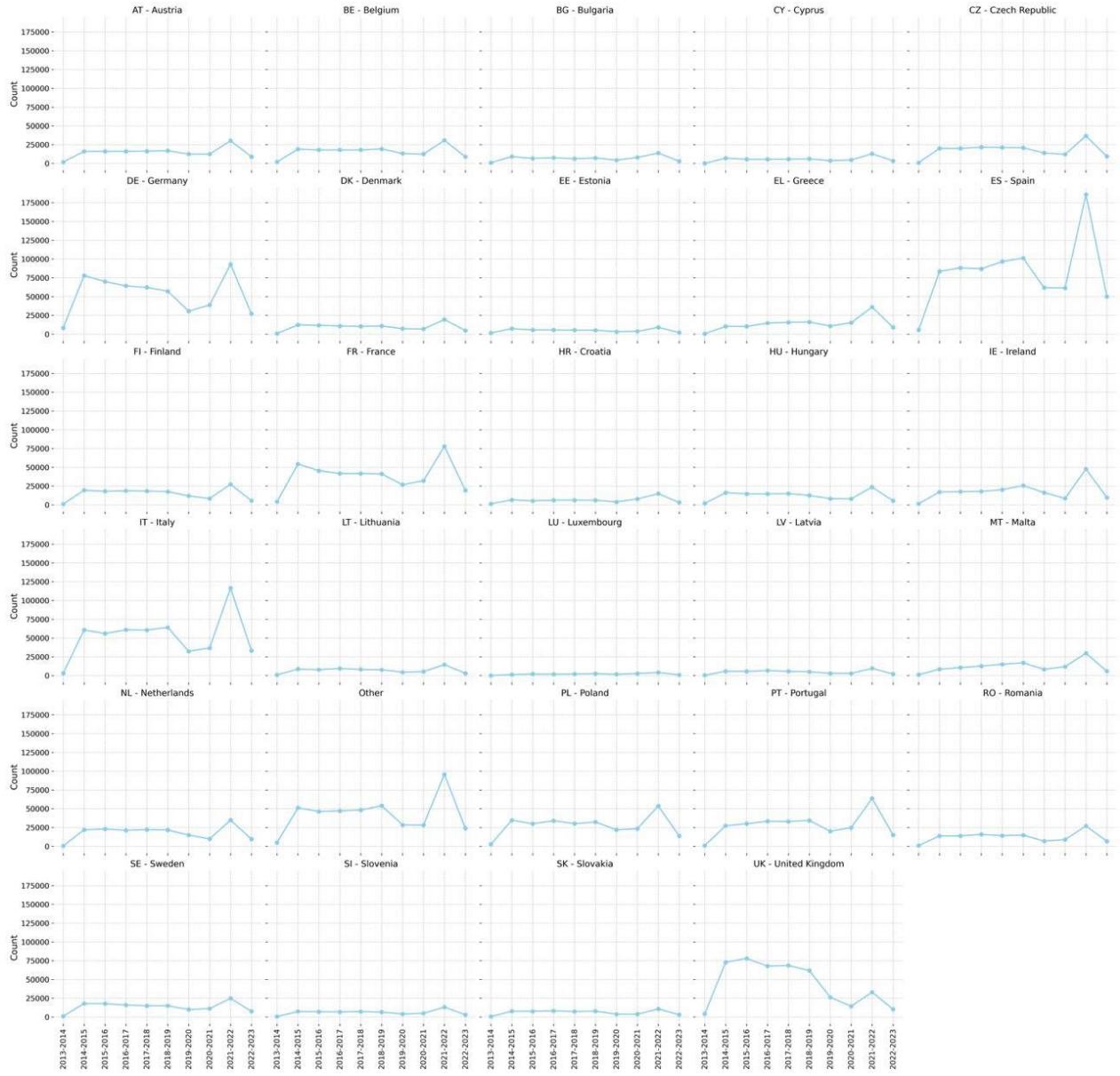

Figure 3: Grid Plot number of incoming mobility each 27+UK as a destination Countries Over Academic years

DOI: 10.13009/EUCASS2025-765

Complementary insights from source (sending) country analysis revealed that Italy, Germany, France, and the UK are among the most active sending nations, reflecting robust national investment in internationalisation strategies. In contrast, Eastern European nations exhibit lower outbound mobility, likely due to economic constraints, institutional barriers, and reduced availability of specialised academic programs in the space sector. This asymmetry contributes to the phenomenon of intra-European brain drain, where students from underrepresented countries migrate toward established educational hubs in Western Europe, often without returning.

3.3 Geographical Distribution of Space Education

A central component of the ASTRAIOS project involved mapping the current landscape of space-related education across Europe. This exercise, detailed in [12], aimed to create a structured and comprehensive database of Bachelor's and Master's degree programmes offered by higher education institutions (HEIs) across the EU-27 and the UK.
The mapping focused on identifying degree programmes explicitly dedicated to or closely aligned with the space domain. These include core topics such as aerospace engineering, Earth observation, satellite communications, space systems design, and space policy. Interdisciplinary programmes that integrate space-related content (e.g., in climate science, data analytics, or remote sensing) were also considered, reflecting the cross-sectoral relevance of space education.
In total, over 350 distinct space-relevant programmes were identified across more than 200 European institutions. Each programme was classified by thematic focus, country, academic level, and language of instruction. The resulting spatial distribution is visualised in Figure 4, where bubble sizes indicate the relative concentration of programmes by country.

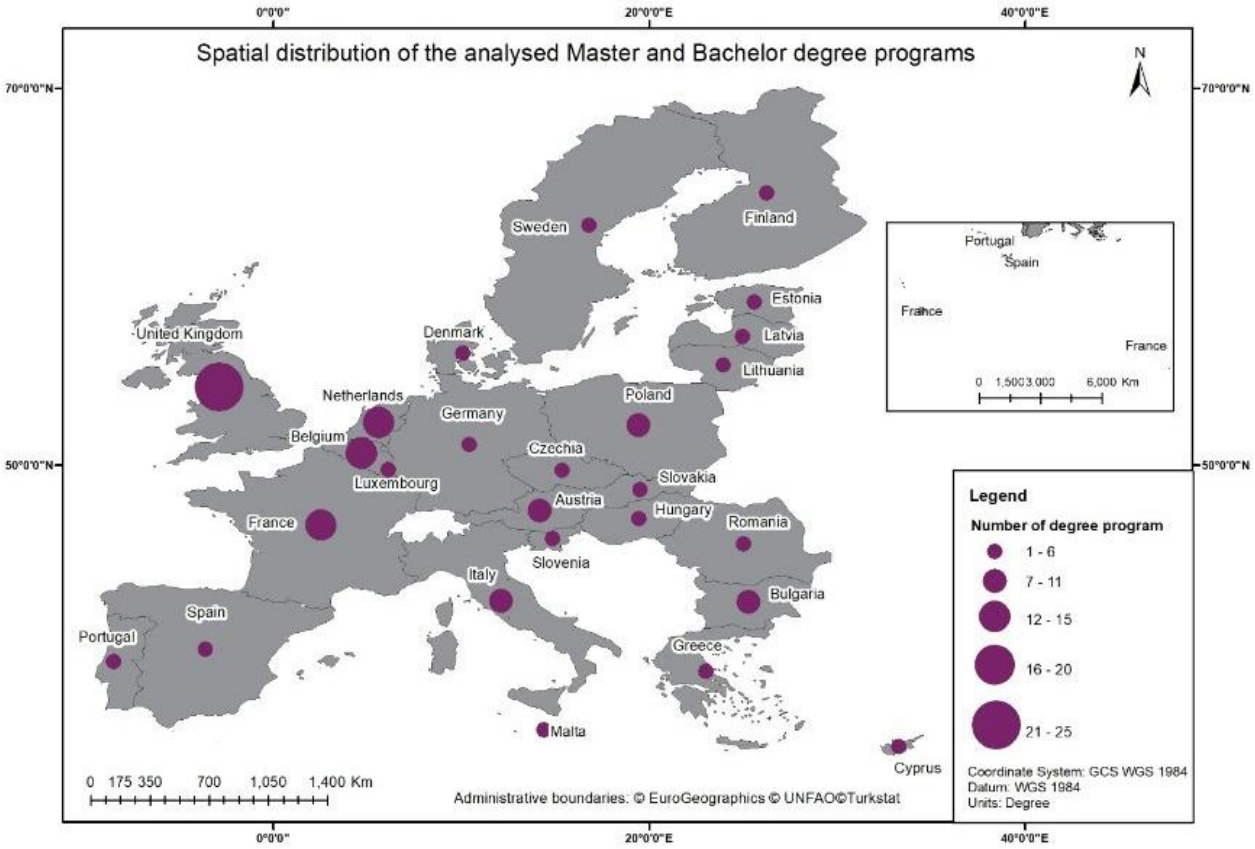

Figure 4. Spatial Distribution of Space-Related Bachelor's and Master's Programmes across Europe

Key findings show a clear concentration of space education offerings in countries such as France, Germany, Italy, and the United Kingdom, regions supported by strong aerospace sectors and national space agencies. In contrast, many Eastern and Southern European nations remain underrepresented, highlighting ongoing regional disparities in access to specialised education.
Content-wise, the curriculum landscape leans heavily toward upstream topics, particularly aeronautics and systems engineering. Midstream and downstream domains, such as satellite data applications, entrepreneurship, or AI in space are less commonly represented, indicating opportunities for curricular innovation in alignment with future workforce needs.

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Further disparities were observed in terms of programme accessibility. While English-taught degrees are increasingly available, particularly at the Master's level, they remain concentrated in Western institutions with higher international visibility. Integration with European standards, such as ECSS, and partnerships with space agencies or industry actors also vary widely across programmes.
This mapping not only benchmarks the current state of space education in Europe but also sets the groundwork for targeted policy actions, such as curriculum harmonisation, better regional coverage, and improved alignment with future space sector demands.

3.4 Language, Tuition Fees and Economic Barriers as a Mobility Factor

The language of instruction significantly influences student mobility. As illustrated in the ASTRAIOS Web-Catalogue, English is overwhelmingly the primary language for space-related curricula across the EU, significantly enhancing accessibility and attractiveness to international students. However, programmes offered in national languages present substantial barriers to student mobility, particularly affecting students from non-English-speaking countries, restricting their opportunities to pursue specialised education abroad.
Analysis of tuition fees reveals critical economic factors influencing student mobility decisions. Programmes in Germany, Austria, and Nordic countries typically offer low-cost or tuition-free education for EU students, significantly enhancing their attractiveness. Conversely, programmes in the UK and certain other countries (such as Malta and the Czech Republic) present higher financial barriers, limiting access for economically constrained students and influencing patterns of student mobility towards more economically feasible options.

3.5 Student Mobility Trends and Barriers

ASTRAIOS survey data collected during WP3 activities reveal that students are primarily motivated to move internationally when offered access to specialised curricula that align with emerging career paths in the space sector. In particular, niche topics such as Earth observation, satellite data applications, and AI in space are cited as key mobility drivers—especially when these programmes are unavailable domestically.
However, several barriers consistently affect mobility. Top constraints include (Figure 5):

- Limited regional opportunities with 28% of respondents highlighting the scarcity of opportunities in their local regions as a primary barrier to internships or job placements.
- Awareness gaps with 26% lacking awareness about available programmes and opportunities, pointing to inefficiencies in communication and outreach efforts by organisations.
- Financial constraints with 12% noting financial challenges, including internship costs and relocation expenses. These constraints disproportionately affect students from economically disadvantaged backgrounds.
- Institutional barriers with Visa requirements (7%) and security clearance needs (11%) adding bureaucratic hurdles, limiting accessibility to global opportunities.

Survey respondents also pointed to a lack of awareness about international opportunities, especially in underrepresented countries. This suggests the need for targeted outreach and centralised information platforms to better support informed mobility decisions.
The analysis of ASTRAIOS surveys highlights key motivations and barriers influencing student mobility in the space sector. Attractive, specialised curricula aligned with career goals strongly motivate mobility, as students frequently relocate internationally to access niche programmes not available in their home countries. Economic factors, including the availability of scholarships and the cost of living, significantly impact mobility decisions. Institutional barriers, such as limited joint or dual-degree programmes, were also highlighted as critical impediments to enhanced mobility.

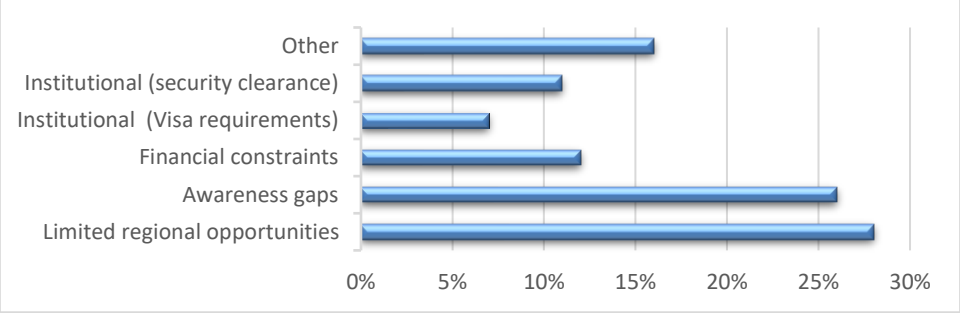

Figure 5. Top 5 Barriers to Student Mobility

DOI: 10.13009/EUCASS2025-765

3.6 Workforce Mobility and Industry Alignment

Analysis of LinkedIn Talent Insights data—covering 170,000+ professionals across 1,800 organisations—highlights a distinct Westward mobility trend among space graduates. Countries like France, Germany, and the UK are leading attractors of talent, driven by larger space industries, greater R&D investment, and stronger academia-industry networks.

Conversely, countries such as Italy, Spain, and many in Eastern Europe experience systemic brain drain, as domestic graduates relocate to Western hubs and often remain there.

The findings underline a misalignment between education systems and workforce demands. While technical qualifications are often strong, reference [13] identifies persistent soft skills gaps in areas such as intercultural collaboration, leadership, and adaptability—skills increasingly demanded by employers in the evolving European space economy.

Strengthening industry-academia partnerships (through internships, co-taught modules, and innovation hubs) is essential to bridge these gaps and retain talent.

4. Recommended Actions

Based on the analysis presented in this study, several strategic actions are proposed to enhance student mobility, address geographical and demographic disparities, and improve the alignment between European space education and the evolving needs of the space industry.

A central recommendation is the standardisation of curricula across space-related programs, supported by frameworks such as the European Taxonomy of Space Knowledge (EU-TaSK). This alignment would simplify the recognition of qualifications, ease student transitions between countries, and ensure consistent educational quality across institutions [11,15].

To overcome the economic barriers that often hinder mobility, particularly from lower-income regions and towards high-cost destinations such as the UK, expanded financial support and dedicated scholarship programs should be introduced. Such efforts should be supported through collaborations among European institutions, national governments, and private stakeholders [9,10]. These financial instruments would play a key role in levelling access to education and promoting inclusion.

Bridging the gap between educational content and industry expectations remains critical. The growing demand for skills in space systems engineering, AI, data analytics, and digital fluency emphasises the need for deeper collaboration between academia and industry. Structured partnerships in the form of internships, apprenticeships, and co-developed training modules would enhance students' readiness for employment and promote innovation in teaching methods [8,13].

Language also presents a notable barrier to mobility. As English remains the dominant language of instruction in most advanced programs, students from non-English-speaking countries face additional challenges. Investing in multilingual education, preparatory language training, and cultural integration support would make space education more accessible and inclusive [10].

Additionally, a widespread lack of awareness about available programs, funding opportunities, and mobility benefits persists.

To promote equitable access, inclusive mobility policies should be reinforced. While female participation in space-related mobility currently exceeds male participation in some areas, greater efforts are needed to address underrepresentation across all demographics, particularly among students from socio-economically disadvantaged backgrounds and underrepresented regions [4,9,15].

Finally, universities should embed soft skills training, such as communication, leadership, negotiation, and adaptability, into formal curricula. These skills, increasingly demanded by employers, are essential in a multidisciplinary and international sector such as space [13]. Practical experience through collaborative projects and mobility can further reinforce these competencies.

By adopting these integrated actions, Europe can mitigate current educational imbalances, foster a more inclusive and agile space education framework, and solidify its leadership in the global space sector.

5. Conclusion

This paper analysed European student geographic mobility within the space sector, leveraging comprehensive ASTRAIOS project database and insights. The analysis revealed significant geographic disparities, highlighting Europe's dominance in space education, with notable underrepresentation in Eastern and Southern regions. Key mobility barriers included language challenges, high tuition fees, economic constraints, and insufficient integration

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between academia and industry requirements. To address these gaps, the paper recommends standardising curricula, expanding financial and linguistic support, enhancing industry-academia collaboration, and strengthening soft skills education. Implementing these actions will effectively improve mobility, bridge educational gaps, and better align space education with Europe's growing workforce demands.

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