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# INTEGRATION OF STEM STRATEGIES INTO VOCATIONAL EDUCATION: A CASE STUDY OF UZBEKISTAN AND BULGARIA

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**Abstract**

This article examines how integrated science, technology, engineering and mathematics (STEM) strategies can inform professional and vocational education in Uzbekistan and Bulgaria. A structured documentary matrix compares the two countries in digital pedagogy, interdisciplinary curricula, educator preparation, industry engagement, inclusion, implementation capacity and quality assurance. The findings identify a shared demand for modular teacher development, applied interdisciplinary projects and green/digital competencies. The study portrays Bulgaria as having more established STEM centres and experience with immersive and gamified tools, while Uzbekistan is described as expanding institutional capacity and policy support. A staged transfer framework is proposed, linking educator development, industry-defined problems, digital learning resources and competency-based assessment. The article concludes that context-sensitive adaptation and measurable pilot studies are prerequisites for credible scaling.

**Keywords:** STEM integration; professional education; vocational education and training; Uzbekistan; Bulgaria; digital pedagogy; comparative case study.

## 1. Introduction

Technical and vocational education faces the dual task of teaching occupationally specific procedures and preparing learners to address complex problems that cross disciplinary boundaries. Integrated STEM teaching offers a route from isolated subject knowledge to evidence-based design, experimentation, modelling and workplace problem-solving [1–2].

The European Union's 2018 Council Recommendation on Key Competences for Lifelong Learning establishes a comprehensive framework encompassing literacy, multilingualism, mathematical and STEM competencies, digital competence, personal, social and civic competencies, entrepreneurship, and cultural awareness and expression [3].

Similarly, the OECD Learning Compass 2030 emphasizes the interconnected nature of knowledge, skills, attitudes, and values in preparing learners for future challenges [4]. Both frameworks highlight the growing importance of integrating specialized professional knowledge

with transferable competencies, commonly referred to as “soft skills”, including creativity, critical thinking, adaptability, responsibility, collaboration, and the ability to address complex problems.

These international perspectives provide a theoretical foundation for reconsidering traditional approaches to professional education, particularly in countries undergoing educational modernization and digital transformation. In this context, STEM-based educational strategies offer opportunities to bridge disciplinary boundaries, strengthen the connection between theoretical knowledge and practical applications, and develop competencies aligned with evolving labor market demands.

Aim of this research investigation: (1) What common STEM integration priorities emerge for Uzbekistan and Bulgaria? (2) What contextual differences affect their potential transfer to professional education? (3) How can the strategic recommendations be converted into an implementable and evaluable vocational education framework?

2. Materials and Methods

A qualitative comparative documentary case-study method and the results of ERASMUS+ KA220-HED project “Master Degree in Integrating Innovative STEM Strategies in Higher Education” (No. 2024-1-BG01-KA220-HED-000253761) were used to prepare this study. The two national cases were selected to evaluate common priorities, implementation analysis, and sustainability provisions of both countries. Analysis of secondary literature was used to interpret STEM integration, competence-based vocational education and digital competence [1–6].

The analytic procedure comprised four stages: (i) extraction of country-specific and shared statements; (ii) coding against seven predetermined themes—curriculum integration, digital tools, educator preparation, workplace engagement, inclusion, institutional readiness and evaluation; (iii) within-case and cross-case comparison; and (iv) development of a vocational transfer framework. Statements in the strategy were treated as consortium-reported assessments, not independently validated national indicators. No interviews, experiments, learner tests or new survey data were collected for this article.

3. Results

**3.1. Shared strategic priorities**

Uzbekistan and Bulgaria education strategy priorities identifies convergence around digital and green transitions, interdisciplinary teaching, professional development for educators, inclusive participation and external stakeholder involvement. It recommends virtual and augmented reality, robotics, gamified learning and AI-supported simulation as potential teaching approaches. For vocational education, the most transferable element is the pedagogical sequence as shown in Fig. 1.

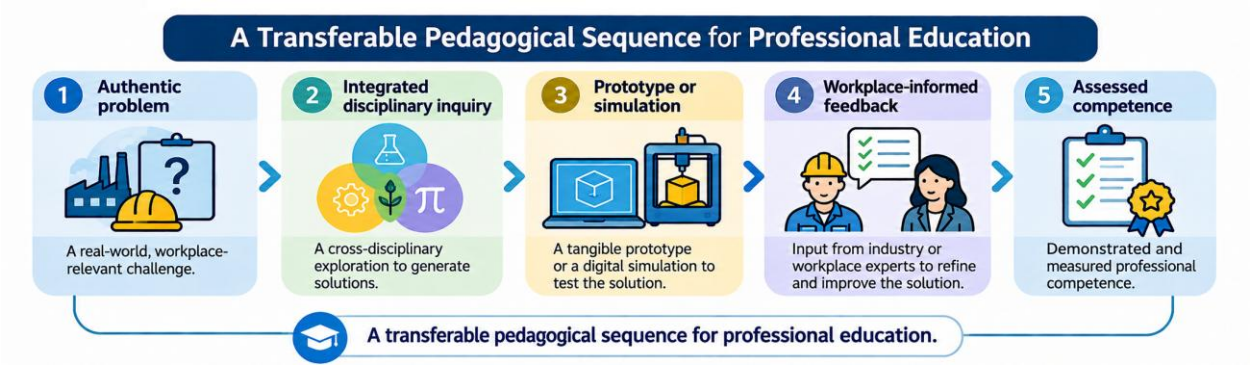



**Fig. 1. Pedagogical sequence for vocational education**.

### 3.2. Uzbekistan–Bulgaria comparison

Comparison between Uzbekistan and Bulgaria system of integrated STEM education characterize Bulgarian institutional readiness as comparatively mature, naming South-West University "Neofit Rilski," Plovdiv University and Shumen University. In the same time it describes Uzbekistan as actively modernizing educational system, prioritizing development of engineering education, the digital learning and international partnerships (Table 1) [6].

**Table 1. Comparison study of Uzbekistan and Bulgaria education system in integrating STEM initiatives**

| Criteria | Case of Bulgaria education system | Case of Uzbekistan education system | Implication for professional education |
|---|---|---|---|
| **Institutional readiness** | Established university STEM centres and experience with digital/gamified teaching | Policy support and ongoing institutional capacity-building | Different entry points for piloting and mentoring |
| **Digital pedagogy** | Reported examples of VR/AR and gamification | Strong motivation and investments; earlier stage of adoption | Start with accessible tools before expensive immersive systems |
| **Teacher development** | Educator interest in modular, flexible STEM training | Educator interest in modular, flexible STEM training | Joint hybrid teacher-development modules |
| **Industry engagement** | Existing university–industry cooperation examples | Linkages encouraged; stronger institutionalisation needed | Co-design employer-authenticated practical assignments |
| **Green STEM** | Climate and energy efficiency themes emphasised | Green digitalisation promoted | Joint resource-efficiency and environmental projects |
| **Evaluation** | Joint monitoring and credit recognition recommended | Joint monitoring and credit recognition recommended | Common rubrics, baseline and follow-up measures |

### 3.3. Proposed vocational implementation pathway

On the basis of the documentary synthesis, the authors propose a five-stage pathway: (1) map occupational standards and define observable competencies; (2) train vocational educators in

interdisciplinary project design and appropriate digital tools; (3) co-design authentic problems with employers; (4) implement blended, accessible STEM projects and workplace practice; and (5) evaluate practical performance, inclusion and sustainability using shared indicator (Table 2).

**Table 2. Stages of development of STEM integrated vocational education**

| Stage | Proposed activity | Evidence of implementation |
|---|---|---|
| **Needs assessment** | Map employer tasks to STEM concepts | Competency map; equipment and teacher audit |
| **Teacher development** | Hybrid modules in project-based learning and simulations | Teaching portfolio; assessed lesson plan |
| **Pilot delivery** | Energy-efficiency or water-quality technical project | Prototype, measurement log, safety checklist |
| **Assessment** | Rubrics for inquiry, design, digital analysis and teamwork | Pre/post practical task scores; inter-rater checks |
| **Scaling** | Peer review and employer feedback | Completion, cost, access and employer relevance |

4. Discussion

The documentary comparison is consistent with research arguing that integrated STEM is most coherent when a meaningful problem connects disciplinary knowledge and engineering design [2]. In vocational education, this means selecting tasks that correspond to occupational standards rather than adding STEM labels to otherwise disconnected lessons. Competence-based vocational education likewise requires authentic performance criteria and alignment between training and workplace activity [7].

The Bulgaria–Uzbekistan contrast suggests differentiated implementation [6]. Bulgarian partners' reported experience with digital and immersive tools may support peer learning and educator exchanges. For Uzbekistan, a feasible first phase may prioritise low-cost data logging, spreadsheets, virtual laboratories and industry-based projects before investing in high-cost equipment

A useful example is a cross-country vocational project on industrial water treatment. Learners could integrate chemistry (contaminant removal), physics (flow and filtration), mathematics (mass balance and error), engineering (system design) and digital skills (sensor logging and visualisation). Employers would define practical constraints; educators would scaffold inquiry; and assessors would use common rubrics.

Future research will pilot comparable STEM modules in vocational institutions in both countries, including evaluation of teacher workload, learner equity and employer-rated outcomes.

5. Conclusion

The comparative case study identifies strong strategic alignment between Uzbekistan and Bulgaria on interdisciplinary STEM, educator development, engineering, digital and green skills, inclusion and industry partnerships. The study describes stronger established STEM infrastructure and digital teaching experience in Bulgaria and growing reform capacity in Uzbekistan. The proposed vocational pathway combines occupational competency mapping, teacher preparation, authentic employer projects, accessible digital tools and transparent performance assessment.

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