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EVIDENCE-BASED DESIGN OF AUTOCAD COURSES IN ENGINEERING EDUCATION: SPATIAL SKILLS, FLIPPED AND PROJECT-BASED LEARNING

Abstract. *The article proposes an evidence-based framework for designing AutoCAD courses in engineering and technical drawing programmes. A review of empirical studies shows that CAD-based instruction improves first-year engineering students' spatial visualisation skills, which also predict success in computer-aided drawing courses; that flipped classroom designs raise course scores by more than 3 percentage points and significantly improve motivation; and that project-based tasks increase satisfaction but may lower grades if they replace systematic practice. On this basis, five design principles and a competency-oriented course structure for AutoCAD are formulated.*

Keywords: *AutoCAD, computer-aided design, engineering graphics, spatial visualisation, flipped classroom, project-based learning, course design.*

INTRODUCTION

Computer-aided design has become the standard medium for producing engineering, architectural and manufacturing documentation, and AutoCAD remains one of the most widely taught CAD packages in universities and vocational schools. As a result, engineering graphics courses increasingly combine two goals: teaching the conventions of technical drawing and developing fluency in CAD software. Researchers emphasise that AutoCAD can serve not only as a drafting tool but also as a means of visualising learning content in engineering and

graphic disciplines (Strelbitskyi & Bovnegra, 2025), and that it allows complex drawings to be produced quickly and accurately while developing students' visual imagination (Tadjibayev, 2026).

At the same time, the way AutoCAD is taught strongly affects what students actually learn. Courses that focus on memorising commands may produce students who can reproduce a sample drawing but cannot plan a drawing independently or read spatial relationships. Teaching materials that lag behind the software version and do not support independent study are reported as typical problems (Muharam et al., 2026). In Uzbekistan, digital transformation of education is a priority of the "Digital Uzbekistan – 2030" strategy (Decree No. UP-6079, 2020), and the Law "On Education" lists the introduction of modern information and communication technologies among the main directions of state policy in education (Law No. ZRU-637, 2020), which makes the question of effective CAD pedagogy particularly relevant.

Research on computer-based engineering graphics education can be grouped into three strands. The first concerns spatial visualisation and its development: spatial skills have been shown to be a key condition of success in engineering education, and they can be improved through targeted training (Sorby, 2009). The second strand examines CAD software as a learning medium, showing that CAD-based courses develop spatial visualisation and that spatial ability is related to performance in CAD courses (Kösa & Karakuş, 2018; Torner et al., 2015). The third strand analyses instructional formats – flipped classrooms, project-based learning and electronic learning modules – and their effects on achievement and motivation (Fang et al., 2022; Li et al., 2016, 2020; Muharam et al., 2026; Vasquez-Monteros et al., 2025).

Publications from Uzbekistan address the theoretical and practical aspects of using AutoCAD in technical drawing, the development of graphic literacy through digital technologies and the formation of students' creative and technical thinking (Tadjibayev, 2026). However, a step-by-step instructional model with explicit time allocation and assessment criteria is rarely specified. At the same time, the gross tertiary enrolment ratio in Uzbekistan rose from 8.1 % in 2015 to 56.5 % in 2024 (World Bank, n.d.-b), which increases group sizes and the pressure on computer

labs and teaching time, while the share of internet users reached 89.5 % (World Bank, n.d.-a), creating the conditions for video-based flipped instruction (Fig. 1).

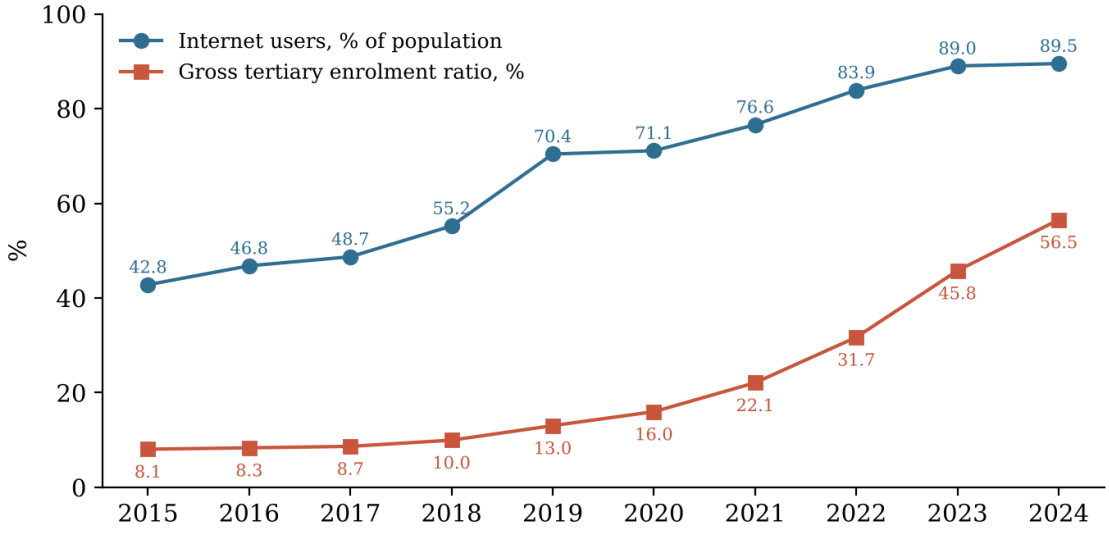

Fig. 1. Internet users and gross tertiary enrolment ratio in Uzbekistan, % (based on data from World Bank, n.d.-a, n.d.-b)

The aim of this article is to synthesise empirical evidence on teaching CAD and AutoCAD and to derive design principles and a course structure for AutoCAD instruction in engineering education.

MATERIALS AND METHODS

The study uses a narrative evidence synthesis. Peer-reviewed studies on CAD instruction, spatial visualisation, flipped classroom and project-based learning in CAD courses were selected from journals indexed in Scopus and Web of Science (Fang et al., 2022; Kösa & Karakuş, 2018; Li et al., 2016, 2020; Sorby, 2009; Torner et al., 2015; Vasquez-Monteros et al., 2025), together with recent publications on AutoCAD teaching from Ukraine, Indonesia and Uzbekistan (Muharam et al., 2026; Strelbitskyi & Bovnegra, 2025; Tadjibayev, 2026). For each study, the context, intervention and main outcomes were extracted and compared. No original experimental data were collected by the author; the proposed framework is a theoretical model that requires empirical validation.

RESULTS

Spatial skills as a prerequisite and an outcome. Long-term research shows

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that 3-D spatial skills, which are critical for engineering graphics, can be developed through targeted training, with benefits for student achievement and retention (Sorby, 2009). In a computer-aided engineering drawing course, CAD-based instruction had a positive effect on first-year engineering students' spatial visualisation skills, and these skills were also a predictor of success in the course (Kösa & Karakuş, 2018). Spatial ability has likewise been studied as a factor in CAD courses (Torner et al., 2015). Spatial skills are therefore both an entry condition and an outcome of AutoCAD learning.

The main findings of the reviewed studies are summarised in Table 1.

Table 1. Empirical evidence on CAD and AutoCAD instruction

Study	Context and intervention	Main outcome
Sorby (2009)	Long-term programme of 3-D spatial skills training for engineering students	Spatial skills can be developed through training; positive effects on achievement and retention
Kösa & Karakuş (2018)	CAD-based computer-aided engineering drawing course, first-year students	Positive effect on spatial visualisation; spatial skills predict course success
Torner et al. (2015)	Spatial ability in CAD courses	Spatial ability is a relevant factor in CAD learning
Li et al. (2016)	Flipped vs lecture-based course in computer-aided landscape design	Scores higher by more than 3 percentage points; higher motivation and attitude ($P < 0.05$)
Li et al. (2020); Fang et al. (2022)	Flipped classroom in CAD courses (Rain Classroom; art design)	Flipped designs applied successfully in CAD teaching
Vasquez-Monteros et al. (2025)	Project-based learning: AutoCAD design of educational board games	Higher satisfaction, but lower grades than the traditional group
Muharam et al. (2026)	Development of an AutoCAD 2D learning module (4D model)	Module developed to replace materials not matching the software version and to support independent learning

Flipped classroom. When a traditional lecture-based course in computer-aided landscape design was compared with a flipped design in which students worked on a teaching case before class, the flipped group scored significantly higher by more than 3 percentage points on average and showed significantly higher learning attitude and motivation ($P < 0.05$) (Li et al., 2016). Flipped designs have also been implemented in CAD courses using the Rain Classroom platform (Li et al., 2020) and in an art and design specialty (Fang et al., 2022). For

AutoCAD, this means that command demonstrations can be moved to short videos, while class time is used for guided practice and problem solving.

Project-based learning. In an Ecuadorian engineering drawing course, students used AutoCAD to design board games on road safety and water conservation for children in rural areas (Vasquez-Monteros et al., 2025). The experimental group reported higher perception and satisfaction, but its grades were lower than those of the control group that followed the traditional methodology (Vasquez-Monteros et al., 2025). Authentic projects therefore increase engagement but should complement, not replace, systematic drawing practice.

Design principles and course structure. Based on the evidence, five design principles for AutoCAD courses are proposed (Table 2), and they are operationalised in a four-block course model (Fig. 2).

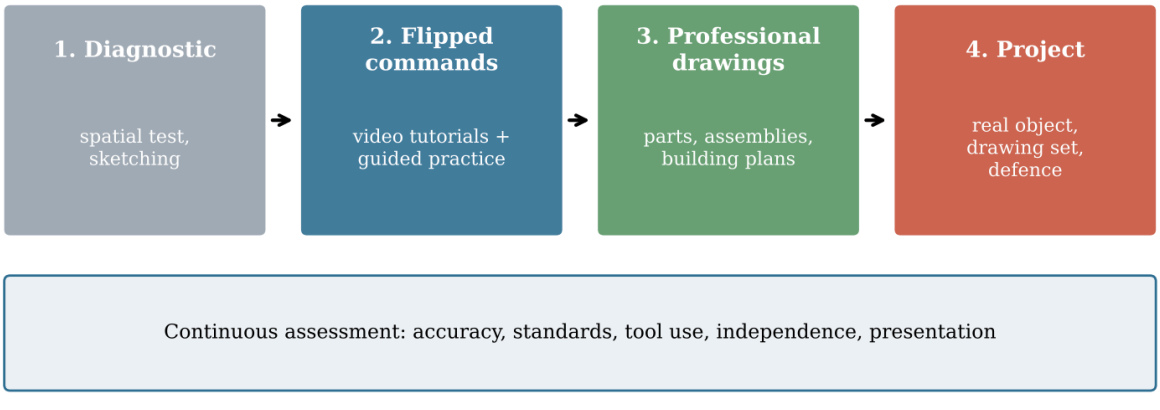

Fig. 2. Four-block model of an AutoCAD course (author's design)

Table 2. Design principles for AutoCAD courses and their evidence base

Principle	Implementation in an AutoCAD course	Evidence
1. Diagnose and develop spatial skills	Entry spatial test; sketching, projection-reading and rotation exercises for low scorers	Kösa & Karakuş, 2018; Sorby, 2009; Torner et al., 2015
2. Flip command learning	Short video tutorials and quizzes before class; in-class guided drawing	Fang et al., 2022; Li et al., 2016, 2020
3. Sequence practice before projects	Basic 2D commands → standard drawings → assemblies and building plans → project	Li et al., 2016; Vasquez-Monteros et al., 2025

4. Use authentic, discipline-specific projects	Real objects from the students' specialty; public presentation of drawings	Vasquez-Monteros et al., 2025
5. Keep materials current and self-paced	Modules matched to the installed AutoCAD version; checklists for independent work	Muharam et al., 2026; Strelbitskyi & Bovnegra, 2025

Following these principles, a one-semester AutoCAD course can be organised into four blocks: (1) a diagnostic and spatial-skills block with an entry test and sketching tasks; (2) a flipped block covering drawing, editing, layers, dimensioning and text; (3) a professional drawings block with part, assembly or building drawings, blocks and templates; and (4) a final project block in which each student or team produces and defends a complete drawing set for a real object from their specialty. Assessment combines geometric accuracy, compliance with drawing standards, efficient use of software tools, independent completion within a time limit and the quality of presentation.

Block content. In the **diagnostic block**, students take a spatial visualisation test, practise reading orthographic projections and freehand sketching, and become familiar with the AutoCAD interface, workspaces and file management. Students with low test scores receive additional spatial exercises, since spatial skills predict success in computer-aided drawing courses (Kösa & Karakuş, 2018). The **flipped commands block** relies on short (5–10 minute) video tutorials and quizzes completed before class, covering drawing (LINE, CIRCLE, ARC, POLYLINE), editing (MOVE, COPY, TRIM, EXTEND, OFFSET, MIRROR), layers, dimensioning and text; class time is used for guided drawing and error analysis (Li et al., 2016, 2020).

In the **professional drawings block**, students produce part, assembly or building drawings relevant to their specialty and learn to use blocks, attributes and templates; peer checking against drawing standards is used systematically. In the **project block**, each student or small team prepares and defends a complete drawing set for a real object, and basic 3D modelling concepts are introduced (Vasquez-Monteros et al., 2025). An indicative allocation of 60 contact hours across the four blocks is shown in Fig. 3: most time is assigned to the second and third blocks, where drawing skills are built through regular practice.

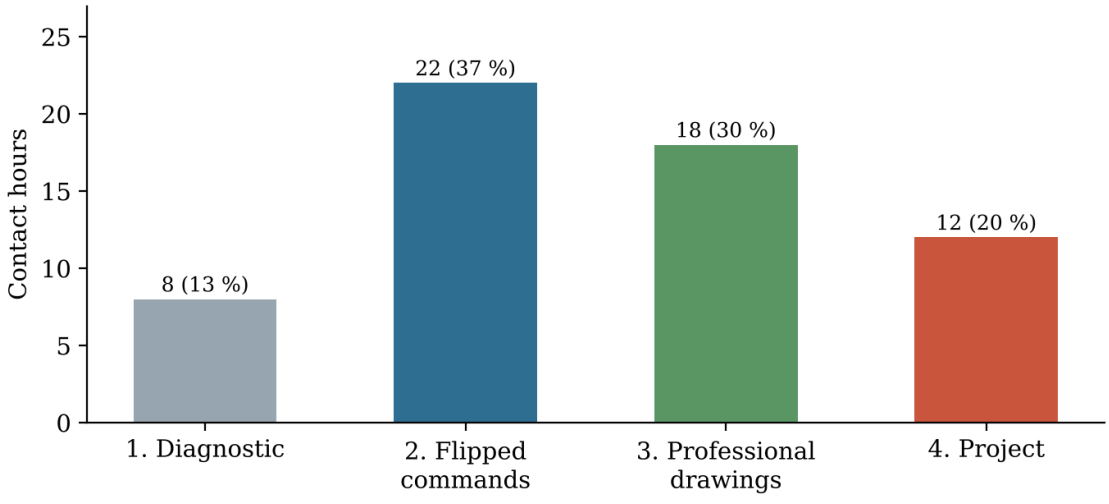

Fig. 3. Indicative allocation of 60 contact hours across course blocks (author's proposal)

A sample structure of an 80-minute flipped session in the second block is given in Table 3.

Table 3. Sample structure of a flipped AutoCAD session (80 minutes)

Phase	**Time**	**Instructor**	**Students**
Before class	–	Posts a video tutorial and a short quiz	Watch the video, complete the quiz
Opening	10 min	Reviews quiz results, answers questions	Identify difficulties
Demonstration	10 min	Shows complex operations	Observe and take notes
Practice	45 min	Coaches, points to errors	Complete a standard drawing independently
Review	10 min	Summarises typical errors	Peer-check drawings in pairs
Closing	5 min	Sets the next pre-class task	Note the assignment

Assessment. Assessment combines five criteria: geometric accuracy (30 %), compliance with drawing standards (25 %), efficient use of software tools (20 %), independent completion within the time limit (15 %), and presentation and defence (10 %) (Fig. 4). The weights are proposed by the author and can be adapted to the programme and specialty; they should be announced at the beginning of the course.

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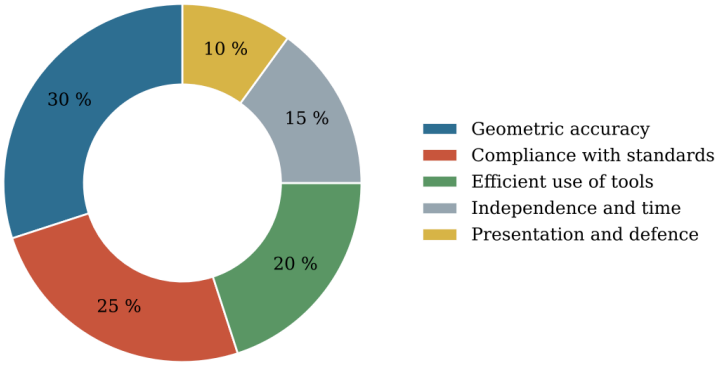

Fig. 4. Weights of assessment criteria for AutoCAD practical work, % (author's proposal)

Typical errors. Novice AutoCAD users tend to make recurring errors; anticipating them and building corrective activities into the course improves efficiency (Table 4).

Table 4. Typical errors of novice AutoCAD users and corrective strategies

Typical error	Consequence	Corrective strategy
Drawing all objects on one layer	Difficult editing and plotting	Use a layer template in every session
Not using object snaps (OSNAP)	Lines do not meet, inaccurate dimensions	Accuracy drills and peer checking
Typing dimensions manually	Dimensions do not match geometry	Require associative dimensioning
Wrong scale or units	Plotted drawing does not meet standards	Teach model space and layouts explicitly
Redrawing repeated elements	Time loss, higher error risk	Teach blocks and arrays (ARRAY)

DISCUSSION

The reviewed evidence suggests that the effectiveness of AutoCAD teaching depends less on the software itself than on how it is embedded in instruction. CAD-based instruction can develop spatial visualisation (Kösa & Karakuş, 2018), but students who enter with weak spatial skills are at risk of falling behind, which justifies early diagnosis and remedial training (Sorby, 2009). Flipped designs appear well suited to software courses because they free class time for practice (Fang et al., 2022; Li et al., 2016, 2020). However, the Ecuadorian experience shows that a highly engaging project may come at the cost of grades if it displaces

the systematic development of drawing skills (Vasquez-Monteros et al., 2025); therefore, in the proposed structure the project block follows rather than replaces the practice blocks.

Several limitations should be noted. Most studies were conducted in single institutions with small samples, and outcomes were measured in different ways, which limits direct comparison. Evidence from Uzbekistan is still limited to descriptive and methodological publications (Tadjibayev, 2026). Controlled studies comparing traditional and evidence-based AutoCAD courses in Uzbek universities, using standard spatial tests and common drawing tasks, are needed to validate the framework.

Several organisational conditions are important for implementing the framework. The AutoCAD version installed in computer labs should match the learning materials, otherwise interface differences hinder students (Muharam et al., 2026). Video tutorials should be short and focused on a single command or operation. Instructors themselves need training in flipped and project-based pedagogy, and assessment criteria should be transparent and applied consistently to every assignment. Together, these measures help AutoCAD courses develop three interrelated groups of competences: graphic competences (reading and producing drawings, applying standards), digital competences (using CAD tools, templates and electronic exchange of drawings) and professional design competences (planning a drawing set, teamwork, presentation) (Strelbitskyi & Bovnegra, 2025; Tadjibayev, 2026).

Proposed validation design. To test the framework empirically, a quasi-experimental study comparing an experimental group taught according to the four-block model with a control group taught in the traditional lecture-and-demonstration format is proposed (Table 5). Spatial visualisation should be measured before and after the course with a standard test such as the Purdue Spatial Visualization Test: Rotations, which is widely used in engineering graphics research (Sorby, 2009), together with common drawing tasks scored with the same rubric and a short survey on motivation and satisfaction. Including affective measures is important because, as the Ecuadorian study shows, satisfaction and grades may move in different directions (Vasquez-Monteros et al., 2025).

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Table 5. Proposed design for validating the AutoCAD course framework

Component	Experimental group	Control group
Instruction	Four-block model: diagnostic, flipped commands, professional drawings, project	Traditional lecture, demonstration and repetition of sample drawings
Pre-test	Spatial visualisation test; entry drawing task	Same
Post-test	Spatial visualisation test; final drawing set scored with the rubric	Same
Affective measures	Survey on motivation, satisfaction and self-efficacy	Same
Analysis	Comparison of gains between groups; correlation of spatial skills with drawing scores	Same

The integration of the course into a learning management system can further support the framework. Video tutorials, quizzes, drawing templates and assessment rubrics can be published in one place, students' files can be submitted and checked electronically, and quiz data allow the instructor to identify difficult topics before class. Such an environment is particularly valuable in large groups, which are becoming more common as tertiary enrolment grows (World Bank, n.d.-b).

CONCLUSION

AutoCAD instruction is most effective when it is designed as part of a broader development of spatial reasoning, drawing literacy and professional design competence rather than as training in software commands. Empirical studies support three components of such a design: diagnosis and development of spatial skills, a flipped organisation of command learning, and authentic projects introduced after systematic practice. The proposed five principles and four-block course structure translate this evidence into a practical model that can be adapted to engineering, architecture and vocational programmes and tested in Uzbek higher education institutions.

REFERENCES

1. Decree of the President of the Republic of Uzbekistan No. UP-6079. (2020, October 5). *On approval of the Strategy "Digital Uzbekistan – 2030" and measures for its effective implementation*. National Database of Legislation of the Republic of

Uzbekistan. https://lex.uz
2. Fang, F., Fan, F., & Wu, H. (2022). Flipped classroom teaching method of computer-aided design course for art design specialty. *Computer-Aided Design and Applications, 19*(S8), 86–95. https://doi.org/10.14733/cadaps.2022.S8.86-95
3. Kösa, T., & Karakuş, F. (2018). The effects of computer-aided design software on engineering students' spatial visualisation skills. *European Journal of Engineering Education, 43*(2), 296–308. https://doi.org/10.1080/03043797.2017.1370578
4. Law of the Republic of Uzbekistan No. ZRU-637. (2020, September 23). *On education*. National Database of Legislation of the Republic of Uzbekistan. https://lex.uz
5. Li, D.-H., Jiang, B.-S., Li, H.-Y., & Liu, X.-P. (2016). Design of experiment course "Computer-aided landscape design" based on flipped classroom. *Computer Applications in Engineering Education, 24*(2), 234–240. https://doi.org/10.1002/cae.21701
6. Li, D.-H., Li, H.-Y., Li, W., Guo, J.-J., et al. (2020). Application of flipped classroom based on the Rain Classroom in the teaching of computer-aided landscape design. *Computer Applications in Engineering Education, 28*(2), 357–366. https://doi.org/10.1002/cae.22198
7. Muharam, R., Wijanarka, B. S., & Rochmadi, H. (2026). Development of AutoCAD 2D module in manufacturing engineering drawing subject for eleventh grade machining engineering students. *Jurnal Pendidikan Vokasional Teknik Mesin, 14*(1), 131–142. https://doi.org/10.21831/jpvtm.v14i1.3583
8. Sorby, S. A. (2009). Educational research in developing 3-D spatial skills for engineering students. *International Journal of Science Education, 31*(3), 459–480. https://doi.org/10.1080/09500690802595839
9. Strelbitskyi, V., & Bovnegra, L. (2025). Advantages of using AutoCAD in teaching engineering and graphic disciplines. *Nauka i tekhnika sohodni*, (1(42)), 975–983. https://doi.org/10.52058/2786-6025-2025-1(42)-975-983
10. Tadjibayev, A. B. (2026). Chizmachilik o'qitish jarayonida AutoCAD dasturidan samarali foydalanish [Effective use of AutoCAD in teaching technical drawing]. *Partner Conferences of the International Scientific Journal Research Focus, 1*(1), 301–305. https://doi.org/10.66073/refocus-conf/2079
11. Torner, J., Alpiste, F., & Brigos, M. (2015). Spatial ability in computer-aided design courses. *Computer-Aided Design and Applications, 12*(1), 36–44. https://doi.org/10.1080/16864360.2014.949572
12. Vasquez-Monteros, J., Samaniego-Rojas, P., & Celi Sánchez, C. A. (2025). Pedagogical strategy in teaching AutoCAD: Designing board games on road safety and water conservation by university students for kids in rural areas. *European Public & Social Innovation Review, 10*, 1–20. https://doi.org/10.31637/

E-ISSN 3069-8375

epsir-2025-1924
13. World Bank. (n.d.-a). *Individuals using the Internet (% of population) – Uzbekistan* (IT.NET.USER.ZS) [Data set]. World Development Indicators. Retrieved November 19, 2026, from https://data.worldbank.org/indicator/IT.NET.USER.ZS?locations=UZ
14. World Bank. (n.d.-b). *School enrollment, tertiary (% gross) – Uzbekistan* (SE.TER.ENRR) [Data set]. World Development Indicators. Retrieved November 19, 2026, from https://data.worldbank.org/indicator/SE.TER.ENRR?locations=UZ